Integration of Self Assessment with a Change Management Process for Deploying Concurrent Engineering

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Executive Summary

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Abstract

The main research theme of this engineering doctorate was as follows: *'How can UK industry effectively leverage concurrent engineering practices within the organisation?'* To address this problem, a review of implementation tools was undertaken, where a number of *'do it yourself'* methodologies were identified within the literature for implementing Concurrent Engineering (CE). These were *'change management workbooks'* and *'self-assessment tools'*. Change management workbooks provide a means for managing an implementation program, and self-assessment measures and benchmarks the deployment of practices and identifying areas for improvement. However, both were found to operate independently from one another. Therefore, it has been proposed that the deployment of CE practice can be further enhanced through an integrated approach. This approach combines both disciplines, because as a system it could measure the deployment of practices, identify future improvements, and enable an organisation to manage the transition to better CE.

To solve this problem a self-assessment tool, which encapsulated practice from the automobile, power generation, aerospace, pneumatics and mechatronics industry sectors was developed. The tool consisted of both a practice and performance dimension to ensure that practices deployed impacted the bottom line. The self-assessment tool allows for a company to assess its current state, and decide where it wants to go. Furthermore, a change management process was developed, which integrated with the self-assessment tool, and a series of additional tools developed specifically for the task such as the generic planning tool, a decision tool for deciding an implementation strategy, and additional tools, which have been selected from the literature.

The application of the system at an UK based organisation demonstrated that a self-assessment tool integrated with a change management process can assist a facilitator to direct a change program toward implementing CE practice. Furthermore, the preliminary results of this application illustrate that the practices deployed as a result of the system were impacting key project performance measures.

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Declaration

I, Matthew Ainscough hereby declare that this work is of my own, and has not been submitted for any other academic degree's unless otherwise stated.

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Glossary of Terms

Benchmarking:

A technique that allows an organisation to analyse practices and performance of direct or non-related industries as a means of understanding the state of the art and comparing an organisations current practices against best practice.

Components Selection Matrix:

A matrix to assist the selection of CE components as a means to decide the organisations future state.

Concurrent Engineering (CE):

CE is the systematic approach to the integrated concurrent design of products and their related processes, including manufacture and support.

Design for Manufacture (DFM):

DFM considers manufacturing related issues during product design.

Design for Cost (DFC):

DFC aims to design and deliver a product to a known set of cost targets.

Design for Customer Requirements (DFCR):

DFCR ensures that customers requirements are encapsulated within the product design.

Design for Reliability (DFR:

DFR aims to design a product to meet set of specified reliability targets.

Design Philosophies Matrix Tool:

A matrix that is applied for understanding the impact of design philosophies upon performance measures.

Generic Planning Tool:

A tool to assist the organisation to plan the implementation of product introduction practices.

Implementation Strategy Decision Tool:

A tool responsible for assisting the selection of a change strategy, be it a big bang, incremental or a pilot approach.

Model:

The word model has been used to refer to a theoretical framework describing the main parts and inter-relationships between those parts that constitute a process or the application of a philosophy.

Process:

The word process has been used with reference to a road map defining a series of chronological activities.

Project Management & Control:

A process based approach which encapsulates four phases, feasibility, planning, implementation and closedown. Its purpose is to enable a project to be planned and executed to meet initial targets.

Scoring Matrix:

A matrix that is applied to the assessment criteria for allocating a score.

Self-Assessment:

A technique for enabling an organisation to self-measure using a set of criteria, and benchmark its performance against a model of best practice.

System:

The word system has been used to define the complete configuration of tools and processes that constitute the self-assessment tool integrated with a change management.

Tailoring Process Tool:

A tool that is applied for tailoring the assessment model towards an organisations specific strategy and customer requirement.

Tool:

The word tool has been used with reference to an aid that assists with achieving an end objective or a set of objectives.

Workbook Change Management Tools:

A process based tool that has been design specifically for implementing a particular practice or a philosophy such as concurrent engineering.

Chapter 1 Background to the Project

1.0 Introducing Concurrent Engineering

Numerous statements exist within the literature that define Concurrent Engineering (CE). However, a commonly quoted definition is stated as follows.

'Concurrent Engineering is the systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support [1, 2, 3]'.

In addition to this, it is important to state that good practice CE represents an organisations ability to not only overlap the process, but to deliver a product on time, to cost, and quality. To further elaborate upon the definition, Prasad believes that a typical concurrent process requires product development phases to be executed as overlapping phases as figure 1 illustrates [4].

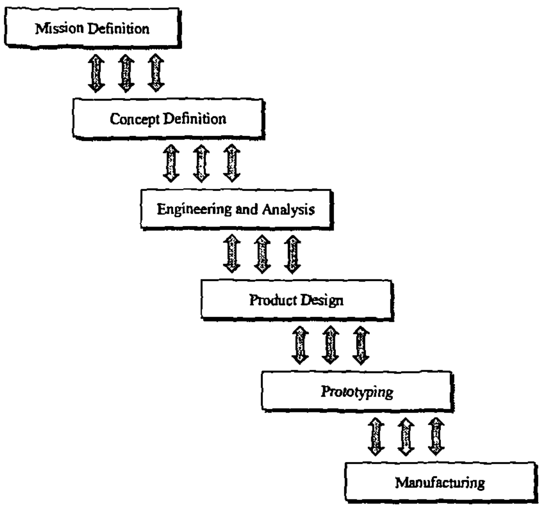

Figure 1 Product Introduction Using Concurrent Engineering[4]

1.0.1) Executing CE: According to Clark and Fujimoto CE requires both two way communication and the partial release of information to downstream processes, where both the designer and manufacturing engineers concurrently take into consideration design and manufacturing requirements at an early stage[5]. However, in addition, Turino also states that CE requires the execution of design philosophies such as: design for manufacture, design for serviceability, design for reliability, design for cost, and design for customer requirements[6]. This is to ensure that a product is designed and delivered to meet cost, quality, and time performance measures.

1.0.2) Benefits of CE: The main objective of CE is to improve new product introduction (N.P.I.) by compressing product development lead-times, and enabling upstream and downstream processes to be considered early within the process. Each will be discussed.

First and foremost, the main benefit from overlapping product development activities, is the ability to compress product development lead-times. This can provide competitive advantage in that an organisation could be a first mover to market, which results in a number of benefits such as[7]:

1) Increased company profits through delivering breakthrough products to market first.
2) Establishing the company as a pioneer of new technologies.
3) Defining industry standards, which dictate that industry followers have to adopt established technologies. This can make a firm's position more sustainable.

4) Establishing protection by filing patents for new technologies and inventions. These provide their owners with exclusive rights for commercially exploiting their inventions.

Secondly, due to CE requiring upstream and downstream functions to communicate and share data early in the process, design decisions can be taken much earlier, where the cost of making design iterations is much lower than if they occurred later within the process[1]. The consequences of design iterations are longer product introduction lead-times due to the length of time it takes to undertake the corrections and an increase in budget spend, due to their high cost[8]. Furthermore, a right-first-time philosophy can lead to a better quality product, as it can be designed to take into consideration downstream processes[9].

1.0.3) Components of CE: CE requires a number of components to be put in place to enable its execution. Nevertheless, although a number of components have been accepted as being enablers of CE, according to Prasad, these have yet to be formalised[4]. However, that is not to say that there is no agreement with respect to how CE is executed. A number of experts within the field commonly refer to a formal N.P.I. process[10], cross-functional teamwork[11] [12], information technology[13], tools and techniques[13] [14], supply chain management, and project management and control for controlling the execution of the project as components of CE[10]. Each of these can be defined as follows:

- A formal N.P.I. process is defined by Phillips et al *as 'a route map which aids the process and enables the efficient and effective movement of a new product from* *idea to launch'*[15]. The purpose of the N.P.I. process is to provide a basis for planning and guiding projects.

- The execution of teamwork within a CE environment requires a team, which Katzenbach and Smith define as *'a small number of people with complementary skills who are committed to a common purpose, performance goals, and approach for which they hold themselves mutually accountable'*[16]. In the context of CE a team has to be cross-functional to ensure a process perspective for developing a product, and led by a team leader who has authority to make decisions.
- Information technology as defined by Daniels is *'the application of I.T. to business processes, gathering data and creating information that is valuable to managers who make business decisions'*[17]. In the context of CE, I.T. can act as an integrating mechanism between functions or dispersed teams where information is centralised, managed and distributed to ensure data integrity and speed.
- Tools and techniques are an enabling technology of CE, in that they aim to define systematic procedures in which decisions can be made early within the process, to ensure that a right-first-time philosophy is taken during product design.
- Supply chain management aims to manage flows through the supply chain, organise its structure to maximise its flow, and continuously aim to improve its links[18]. Within a CE environment, the main objectives of supply chain management are to include the supplier as early as possible during the process, and to ensure that the supply chain is aligned to support CE activities.
- Project management as defined by Lock is the process of *'predicting and foreseeing as many dangers as possible during the life-cycle of a project, and to plan and control activities so that a project can be completed on time to cost, budget, and to quality'*[19]. Within a CE environment effective project management

is essential for planning and driving a project to meet the objectives set for the project.

1.1 Introduction to the Problem

As established within the previous section, CE brings many competitive benefits to an organisation. Yet, although considerable evidence exists within the literature which demonstrates that CE is being applied within industry, recent research has concluded that not all UK organisations had taken up CE[20]. Within certain industry sectors such as Power Generation, Petrochemical and Aerospace, CE was found to be high. In other industry sectors such as Automobile and Machinery its take up was found to be relatively low as figure 2 illustrates. Nevertheless, it has to be said that the relatively low maturity of the car industry was surprising, as a higher percentage of companies practising CE was expected due to the amount of literature focusing upon CE within the Automobile industry.

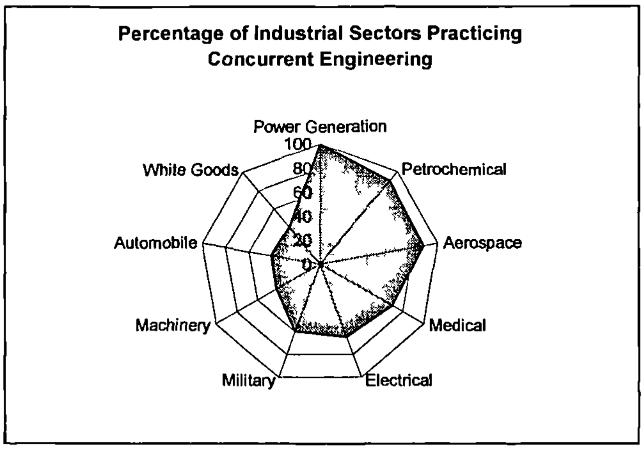

Figure 2 Percentage of Industrial Sectors Practising Concurrent Engineering[20]

Furthermore, questions must also be asked of those companies who claim to practice CE, as to whether they are mature in its execution, and whether they deliver a product on time, to cost and quality. Viness et al found that when assessing the deployment of CE and its level of maturity within large UK companies, 50% stated that they were not fully mature, whilst only 38% claimed to be mature[21].

Therefore, the following question can be asked. Why is CE and its deployment within UK industry relatively low? An investigation into the problems associated with change suggest that the low take up of CE is due to poor management of the change process as the following quote suggests, *'70% of all companies who embark upon a business process re-engineering program will fail'*[22]. In addition to this, Kotter also states that companies often struggle to manage change, because they do not take a process based approach, and they look to take short cuts by expecting individuals to execute new working practices without training or any awareness of its need[23]. Yet, evidence suggests that there is not a lack of motivation to manage change, as a recent survey implies. Due to globalisation of markets, and increased competition, 96.6% of business managers believe that achieving change is the foremost business issue of the day[24]. Therefore this suggests that the low take up of CE within UK industry is not due to a lack of motivation for its implementation, but may well be attributed to managers not knowing how CE should be deployed within the organisation.

1.2 Objectives

Therefore, the main theme underpinning this Engineering Doctorate can be stated as follows:

'How can industry effectively leverage concurrent engineering practices within the organisation?'

This resulted in the following research objectives.

- To develop a system, which will enable the implementation of CE practices.
- To verify that the system is effective by applying it within an organisation.

A system, which will enable the implementation of practices could help to assist those organisations, who have yet to take up CE or are currently in the process of doing so.

Chapter 2 Research Methodology

2.0 Introduction

This chapter aims to present the research process and the research techniques deployed for developing the tool.

2.1 Research Process

To develop the tool for assessing and implementing CE, a research process consisting of four phases was applied as shown in figure 3.

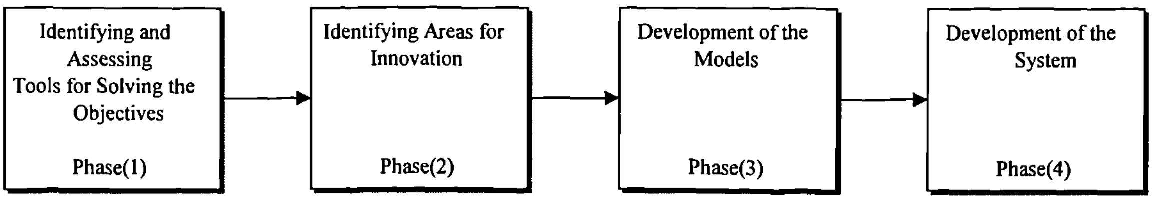

Figure 3 Research Process

- Phase one of the research process was executed to investigate with a literature review (see section 2.2.1), the different tools available, which could potentially provide a solution for companies to implement CE. Furthermore, once identified, each tool was compared to one another so that an appropriate tool could be identified. This identified self-assessment integrated with a change management process as being a potential solution.
- Phase two of the research process aimed to identify areas where potential innovation could be achieved. This investigated in greater detail current self-

assessment tools and change management workbook tools available within the literature (see section 2.2.1), and developed specifically for implementing CE. By reviewing and understanding their strengths and weaknesses, gaps were identified, which resulted in a set of requirements for a new tool.

- During phase three of the research process, a model of CE practice, and a change management process model, which could potentially direct a change program was defined using a literature review (see section 2.2.1). Furthermore, this phase also aimed to verify that the conceptual models defined were representative of practices adopted by British Industry; this was achieved by comparing and contrasting both approaches. To execute this phase, the survey (see section 2.2.2), and the case study method (see section 2.2.3), were used to ensure further validation and more in-depth understanding.
- Finally, during the fourth phase of the research process, a self-assessment tool integrated with a change management process was developed and tested. The requirements defined in phase two were used to guide its development, with the CE model and the change management process model developed in phase three being central to the tool. To test its applicability, the potential solution was applied within an organisation. To execute this, an action research methodology was deployed (see section 2.2.4).

2.2 Research Techniques Deployed

2.2.1) Literature Research: As previously stated, a literature research was conducted during phases 1, 2, and 3 of the research process, so that current state of the art could be identified and understood. A number of database sources were used:

- OPAC, University of Warwick Library system;
- BIDS an online literature data base;
- Pro-Quest Direct; a literature database accessed via the internet;
- Infotrac, a literature database accessed via the internet;
- EBSCO, a literature database accessed via the internet;
- Index to thesis, a library resource used for reviewing PhD's.

Within these databases both journals and business books were accessed.

2.2.2) Quantitative Techniques: As previously stated, the survey method was deployed in phase 3. This method can be classed as a quantitative approach where a researcher looks to collect quantifiable data, which can be analysed through using statistical techniques[25]. This normally requires the definition of a set of hypotheses, and the analysis of quantifiable data for finding proof. The survey method was deployed to gain quantifiable evidence, to verify whether the components of CE defined within the conceptual model were representative of industry. To apply this approach, a survey was designed, which targeted 1400 companies, representing a diverse range of industrial sectors. An external data base source, where specific characteristics can be queried to select these companies was used. Particular queries were whether the company undertook new product development, whether the individuals targeted were senior management, and whether they operated within a specified range of industry sectors. A 10% response rate was received that led to 140 responses being analysed.

Six hypotheses were stated and tested, these were as follows.

- **Hypothesis One:** Organisations that practice CE have a greater dependency upon utilising a new product introduction process as a means of guiding product development activities than organisations who bring their products to market by using a sequential process.
- **Hypothesis Two:** Organisations that practice CE have a greater dependency upon cross-functional team working practices for executing product development in parallel than organisations who bring their products to market by using the sequential process.
- **Hypothesis Three:** Organisations that practice CE have a greater dependency upon process orientated tools as a means for integrating product development than organisations who practice the sequential process.
- **Hypothesis Four:** Organisations that practice CE have a greater dependency upon tools such as Quality Function Deployment, Failure Mode & Effects Analysis and Design for Manufacture for enabling product development than organisations who practice a sequential process.
- **Hypothesis Five:** Organisations that practice CE have a greater dependency upon supply chain management techniques, which emphasise upon communication than organisations who practice a sequential approach to product development.
- **Hypothesis Six:** Organisations that practice CE have a greater dependency upon project management tools than organisations who practice a sequential approach to product development.

These were defined because within the literature a number of tools and methodologies were reported to be essential for enabling CE. Therefore, a greater dependency upon these tools would be expected within organisations that are highly concurrent. To test these hypothesis, companies were segregated into three distinct categories, 'high concurrent' organisations, 'medium concurrent' organisations, and 'low concurrent' organisations. This approach was achieved by asking the respondent to state when they began their manufacturing concept definition relative to the product development life cycle so that they could be classified. To test whether significant differences were found between these groups, contingency tables were used, which is a non-parametric test for analysing tables of counts.

2.2.3) Qualitative Techniques: As previously stated, within phase 4 a qualitative technique was deployed for verifying the model of CE practice and the change management model. A qualitative approach is a technique, which cannot be easily reduced to numbers and in some cases to do so, would not provide any value[25]. To further verify the components of CE, and to find evidence to support the change model, a qualitative approach was deployed through developing case studies. Yin describes the case study as follows.

'An approach, which investigates a contemporary phenomena within its real life context, when the boundaries between phenomena and context are not clearly evident and which multiple sources of evidence are used[26]'.

To build the cases for verifying the model of CE, eight case study companies were selected as table 1 illustrates. Furthermore, a questionnaire was deployed using face-to-face interviews with key senior company members who were responsible for new product introduction. The reason why these two techniques were used as opposed to others, such as observing operations, was mainly due to the time constraints given by organisations in which to collect data. A face-to-face interview and a questionnaire meant that interactive questions could occur, and documentation could be achieved. Nevertheless, there were limitations in that the information could not be cross-checked with actual operations to see if it represented reality.

Company	Development Locations	Product Complexity	Activities
Rolls Royce	National multi Site	High	The design and development of gas turbines for powering commercial airlines.
Airbus/BAE	European multi-site	High	The design and development of commercial aircraft wings.
Rover/BMW	National multi-Site	High	The design and development of automobile vehicles.
Alstom	National multi-Site	High	The design and development of gas turbines for industrial applications.
Lucas/Varity	National multi-Site	Low	The design and development of automobile products for vehicles.
Parker Pneumatic	Site	Low	The design and development of pneumatic products.
Integrated Design	Site	Low	The design and development of door security products.
C&H Howe	Site	Low	The pressing of components for the automobile industry.

Table 1 Companies which Participated within the Study

The companies selected were representative of the automobile, power generation, aerospace, pneumatics, and mechatronics industry sectors, they developed either complex or non-complex products and they operated within a site, a national multi-site or a European multi-site domain. These companies were selected for a number of reasons.

1. A diverse range of development locations was selected to ensure that the model of practice represented these product development scenarios.
2. A diverse range of industry sectors was selected as opposed to one because it was important to gain a representation of industry so that commonalities could be identified. However, there were limitations with respect to selecting companies in that their consent was essential, and this proved at times to be difficult to achieve.

3. The companies selected were known to practice CE. Questionnaires, literature confirming CE practice and recommendations from experts in the field of CE were used to confirm their applicability.
4. The influence of product complexity in company selection was due to an observation made within the questionnaire survey. A potential correlation was identified between product complexity and the use of specific CE components.

To compare the case studies against the CE model, so that correlations could be observed, a comparative analytic technique was deployed. The comparative analytic technique is a method of investigation that aims to identify commonalities between two or more sets of data. To verify the model, key practices of the CE model were compared to practices, which had been deployed within each case study company. The number of companies that agreed with the model denoted the level of correlation.

To verify the change model, the literature of two case companies who undertook change toward competitive new product introduction was used. The Rover/BMW case study was defined using the Executive Summary of Dr. Charles Tennant, titled *'Deployment of a Company Wide Quality Strategy in the Automotive* Business'[27]. The Lucas case study on the other hand was defined using the paper written by Dr. Allen Parker *'Implementation of Product Introduction Management in a Large Multi-National Company'*[28]. Again to identify the relationships between the cases and the models, the analytic comparison technique was used. The key phases and activities of the change model for implementing CE were compared against the key activities executed by each case study company, so that a level of correlation could be established.

2.2.4) Action Research: To verify that the solution identified was useable and added value to organisations, it was tested at London Taxis International. A re-engineering project took place, which aimed to define and implement a formal N.P.I. process. To test the solution, an action research methodology was deployed, which can be defined as the following.

'The process of systematically collecting data about an ongoing system relative to some objective, goal or need of that system; feeding back data into the system; taking action by altering selected variables within the system based on the data and hypothesis, and evaluating the results of the actions by collecting more data[29]'.

The action research methodology was used, because the Research Engineer (R.E.), and the change management team agreed to work together. This provided the R.E. with the opportunity to test the following hypothesis.

'A self assessment tool integrated with a change management process, can facilitate a change program within an organisation toward effective product development practice'.

The role of the R.E. was to facilitate the workshops, capture knowledge, process map the N.P.I. process, and to provide tools and guidance. The role of the change management team was to provide knowledge of internal business processes so that they could be captured within the process mapping sessions, and to implement the process within the business.

2.3 Overview of Submissions

To assist the research process, six submissions were written, which documented key parts of the development of a tool for implementing CE as a means for improving N.P.I..

2.3.1) A Critique of New Product Introduction Auditing Tools: Phase two of the Research process (see section 2.1) was reported within Submissions One and Five, where potential areas for innovation were identified.

2.3.2) Defining a Conceptual Model for Enabling CE: The first part of phase three of the research process (see section 2.1) was reported within Submission Two, where a conceptual model of CE practice was defined.

2.3.3) Investigating CE within British Industry: The second part of phase three of the research process *'verifying the models'* was reported within Submission Three (see section 2.1). This submission documented a survey of UK industry and it presented an analysis of whether the practices supported the six hypotheses proposed (see section 2.2.3). Furthermore, this work led to a paper titled 'Concurrent Engineering within British Industry', which was presented and published at the Sixth ISPE International Conference on Concurrent Engineering: Research and Applications, Bath, United Kingdom, September 1-3, 1999. Moreover, it was also published within the International Journal of Concurrent Engineering: Research and Applications, Volume 8, Issue 1, 2000, P2-11.

2.3.4) Verification of a Conceptual Model for Enabling CE: The third part of phase three of the research process *'verifying the models'* was documented within Submission Four (see section 2.1). This reported on the comparison of eight case study companies against that of the CE model (see section 2.2.4) as a means to verify whether the conceptual model represented their practices. This work led to a paper titled *'Concurrent Engineering for Complex Products and Projects'*, which was presented at TMCE 2000, Third International Symposium on Tools and Methods for Competitive Engineering, Delft University, Holland.

2.3.5) The Development of a Change Model for Implementing CE: The final part of phase three of the research process was documented within Submission Five (see section 2.1). This presented a conceptual model for enabling change, and reported a study, which aimed to verify that the concept model defined compared with two case study company's approaches to change.

2.3.6) Definition and Verification of a Tool for Assessing and Implementing CE: Phase four of the research process was documented within Submission Six. This describes the development and verification of the self-assessment tool integrated with a change management process.

2.4 Reading the Submissions

Each submission can be read in a chronological order from submission one to six, and their purpose is to support the Executive Summary. In addition to these, two papers were included, which have been presented and published within International

Conferences, and Journals. Each paper should be reviewed simultaneously with each appropriate submission. This overall process is documented within figure 4.

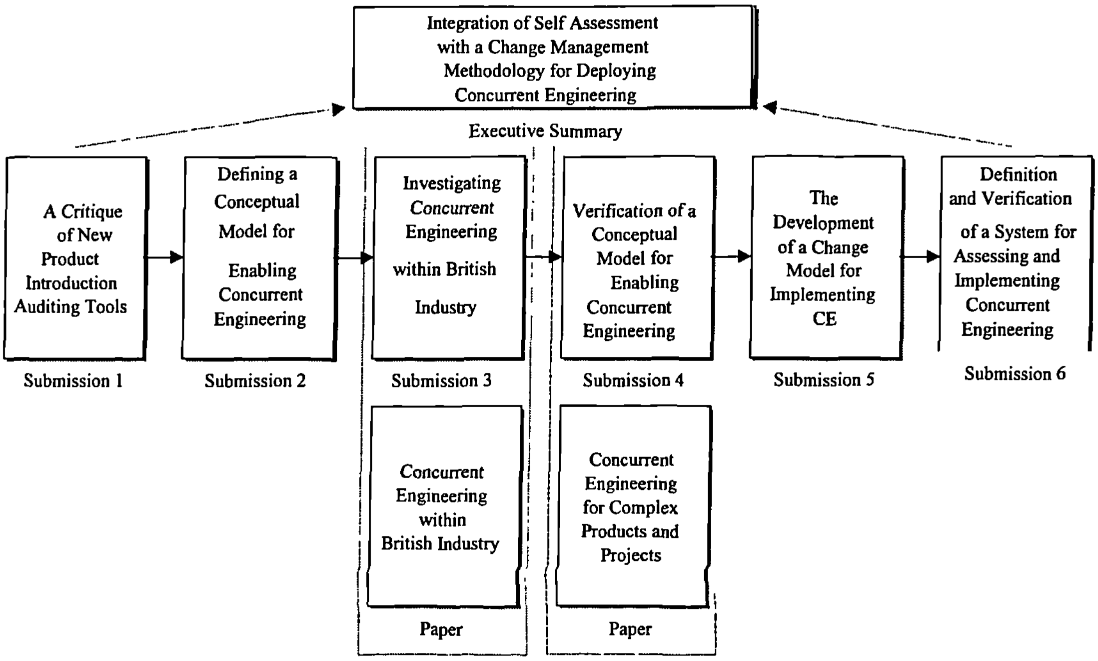

Figure 4 Order of Reading the Submissions

2.5 Summary

This chapter presented the research process deployed for developing the self-assessment tool integrated with a change management process by explaining each phase, and the research techniques deployed. A wide variety of research techniques were used throughout the course of the project, which included literature research, quantitative and qualitative research methods and the deployment of the action research method. Furthermore, the key phases of the research process were documented within six project submissions within the Engineering Doctorate portfolio.

Chapter 3 Selecting a Tool for Implementing CE

3.0 A Review of Potential Tools for Enabling Change to CE

According to the Oxford Dictionary, change is defined as *'the act or the instance of making change or becoming different'*. This implies that change is not only the phenomena of becoming different, but also the process of getting there. Furthermore, Grundy believes that three types of change exist: smooth incremental, bumpy incremental and discontinuous change[30]. Smooth incremental change is characteristic of a business environment which evolves slowly and at a predictable rate. Bumpy incremental change represents periods of slow and fast change, where often at its peak, major restructuring is required. Finally, discontinuous change represents a period where a major shock to the system leads to major unpredictable change.

The purpose of this chapter is to identify a system, which could enable industry to manage change toward CE and improve N.P.I.. According to Carter and Baker, this requires the execution of three phases, *'where are we now'*, *'where do we want to go'*, *and 'how do we get there'*[1]. To do this, a literature review was executed by the R.E. to identify tools that could enable organisations to implement CE.

3.1 Introducing Tools & Processes for Enabling Change

A number of tools were identified within the literature, which could address the issue of understanding an organisation's current and future state against a model of practice, and enable change to be controlled. These are self-assessment, benchmarking, SWOT, auditing, kaizen, project management and control, policy deployment, and workbook implementation approaches.

3.1.1) Self-Assessment: Self-assessment is a tool that enables an organisation to measure its performance against a number of dimensions. This tool allows an organisation to translate qualitative evidence, representing the deployment of practices, into a quantifiable score for understanding its maturity and identifying areas in which it can improve. Therefore, self-assessment is a tool that can measure the current state and assist in planning the future state of an organisation. A more formal definition is quoted as follows:

'A comprehensive, systematic and regular review of an organisation's activities and results referenced against a model of business excellence. The self-assessment process allows the organisation to discern clearly its strengths and weaknesses, which improvements can be made and culminates in planned actions, which are then monitored for progress'[31].

3.1.2) Benchmarking: Benchmarking is a tool that allows an organisation to analyse practices and performance of direct competitors, or non-related industries as a means of comparing an organisation's current state against best practice. This allows it to understand its gap as the following definition implies[32].

'Benchmarking is a formal process for rigorously measuring your performance versus the best in class companies and for using the analysis to meet and surpass the best in class[32]*'*.

Benchmarking often requires a visit to a competitors facility or an industry sector leader, where a review of the targeted operations is undertaken.

3.1.3) Strengths, Weaknesses, Opportunities, Threats: SWOT is a tool that can assist the strategic management process by allowing information to be organised so that a company can understand its Strengths, Weaknesses, Opportunities and Threats. SWOT analysis is a powerful tool as it can be applied to a series of problems such as identifying an organisation's current strengths and weaknesses, and identifying opportunities for improvement. However, SWOT does not provide knowledge; but it does provide a means for its structuring.

3.1.4) Auditing: Auditing is a tool used by management or an external body to understand a company's current status with respect to evaluating assertions. Furthermore, Anderson states that auditing is a method for evaluating internal controls, and enforcing the current status quo[33]. A definition of Auditing is given as follows.

'The systematic process of objectively gathering and evaluating evidence relating to assertions about economic actions and events in which the individual or organisation making the assertions has been engaged, to ascertain the degree of correspondence between those assertions and established criteria, and communicating the results to users of the reports in which the assertions are made'[34].

Auditing can be classified into three categories: financial, compliance, and operational audits. Financial audits are concerned with analysing a company's financial statement.

Compliance audits aim to determine whether a company or an individual is acting in accordance with procedures and regulations. Finally, operational audits focus on company operations to identify areas for improvement.

To understand an organisation's current and future state, operational audits can be used. Operational criteria should be defined within the audit, and the role of the auditing team is to collect evidence, and assess the organisation against the criteria. This can be used to determine whether the organisation complies against the criteria specified. Once completed, the auditing team reports their findings to senior management, so that action can be taken.

3.1.5) Kaizen: Kaizen is a continuous improvement process to enable change[35]. Central to Kaizen is the Deming Cycle, which includes the phases, 'Plan', 'Do, 'Check', and 'Act'. The ability to achieve change is central to this cycle, as it allows an organisation to understand its current and future state, and plan how to get there. Kaizen is fully leveraged when a company forms quality circles for creating an environment of teamwork. Each quality circle consists of a complementary group of individuals, who are responsible for finding and implementing new solutions.

3.1.6) Project Management & Control: Traditionally *'Project Management & Control'* was associated with the delivery of big budget construction projects. However, its value has been realised in many other applications such as introducing new products to market and managing change. Essentially project management & control is a process, with four main phases; feasibility, planning, implementation, and closedown, which aim to plan, organise, and control activities[19]. Furthermore, it is also supported by tools such as gannt charts, pert diagrams, and resource histograms.

3.1.7) Policy Deployment: Policy deployment is tool used for deploying Total Quality Management[36]. Arguably TQM has a broad scope, which can include the implementation of CE. The execution of policy deployment requires top management to define policies and specific means for their realisation. The means defined at this level then become the policy at the next level, and this requires middle management to develop specific means for its realisation. Thus, the process cascades down each management tier level[36].

3.1.8) Workbook Change Management Tools: Numerous models for enabling change exist within the literature such as those proposed by Cummins and Worley[37], Bullocks and Battens[38], Lewin[39], and Kotter's[23] model of change. However, these models are top level in nature, and they require tailoring for implementing CE. Workbook change management tools on the other hand are process-based approaches that have been designed specifically for implementing a particular practice such as CE, through using a project management and control related approach[40,41,42]. The purpose of these tools is to provide organisations with the means to leverage practice through a 'do it yourself approach'. The argument for such an approach is that an organisation can develop its own competence and expertise, rather than use expensive alternatives such as consultants or undertake a major benchmarking exercise.

3.2 Comparing and Contrasting Tools

A number of tools and processes were introduced in the previous section for enabling organisations to review their current state, plan where they want to go, and assist the control of change. To select a tool or a process for implementing CE, each was compared and contrasted against one another as a means of identifying the best tool for meeting the objectives. This was achieved by defining a set of criteria with which to compare them by using the survey of Lawson and Karandikart[43]. Among 70 US companies, the survey identified a number of common barriers to implementing CE. These are shown in table 2.

Barriers	Response
Natural Tendency to Not Change	73%
Poorly Defined CE Process	52%
No Good Measurements to Guide Change	50%
Little CE Training Available	49%
Little Experience with the Change Process	37%
Little Understanding of the Need to Change	32%
Lack of Approved CE Standards	28%

Table 2 Barriers to Implementing CE[43]

Based on these survey findings, the following criteria were defined for identifying a solution that could assist UK organisations to implement CE.

1. *Provide built in knowledge of CE to enable transfer of best practice.*

A solution that provides built in knowledge of CE can ensure that an organisation defines an effective CE process quickly and easily. This addresses the survey findings 'a poorly defined CE process' and a 'lack of CE standards' as barriers to its implementation as knowledge will be provided to assist its definition.

2. *Allow an organisation to identify its current state and compare itself against best practice CE to identify where it wants to go.*

Measuring 'where you are now' and 'where do you want to go' addresses a number of barriers to CE. 'Little understanding of the need to change' would be addressed by a gap analysis emphasising an organisations current and future state, as it will demonstrate its need to change. In addition by understanding the gap between 'where are you now' and 'where do you want to go' on a periodical basis, 'no good measurements to guide change' would also be addressed because as change takes place, progress would be observed.

3. *Provide a scoring method that allows quantifiable comparisons to be made to ensure that an accumulated score is robust, and not based on anecdotal evidence.*

A scoring system further addresses the barrier 'no good measurements to guide change' as it will provide a method that will enable a quantifiable score for measuring the maturity of CE and its progress to be defined.

4. *Provide a system that is easy to apply and enables an organisation to use a do it yourself methodology.*

To overcome the barrier 'little experience of the change process', a solution is required that is easy to apply, so that a do it yourself approach can be utilised.

5. *Involves Everybody*

According to Deming, to create an environment for enabling continuous improvement requires the input of everybody; this includes both management and the worker[44].

Therefore, to overcome the barrier 'a natural tendency to not change' requires a system that will include a breadth of individuals from the organisation to focus upon enabling change. In reality to 'involve everybody' in the process would not be feasible but, individuals who are included must represent a sample of top, middle, lower management and the workforce to enable change.

6. *Enables organisations to identify key phases for managing change, thus allowing for activities to be planned.*

A tool that identifies key phases to enabling change and provide a route map for defining a project plan, can address the barriers 'little experience of the change process' and a 'natural tendency to not change'. A route map defining phases of change can assist the organisation by making clear the key activities required for leveraging practice to ensure a successful change program.

	Self-Assessment	Benchmarking	SWOT	Auditing	Kaizen	Policy Deployment	Project Management & Control	Work-book Implementation Methods
Knowledge of CE	Yes	No	No	Yes	No	No	No	Yes
Measure Current & Identify a Future CE State	Yes	Yes	Yes	Yes	No	No	No	No
Provide a Scoring System	Yes	No	No	No	No	No	No	No
Easy to Apply	Yes	No	Yes	Yes	No	No	No	Yes
Involves Everybody	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Identifies Key Phases for Change	No	No	No	No	Yes	No	Yes	Yes

Table 3 Comparison of Tools for Implementing CE

To assess the tools, table 3 demonstrates how they compare against one another with respect to achieving the criteria defined above. To undertake this task, the research engineer (RE) used each criterion for comparing and contrasting the tools with respect to their ability at achieving it. The results of this will be discussed.

- **Knowledge of CE:** Self-assessment, operational audits and workboook change management tools compare and contrast in a number of ways as table 3 illustrates[31,33,41,42]. They compare in that they provide a knowledge base of CE within the tool and hence a **'yes'** has been placed within table 3. Nevertheless, they contrast in that knowledge of CE within self-assessment and operational audits are documented in detail using criteria defined for assessing the organisation[31,33]. Workbook change management tools on the other hand define a model of CE at a relatively top level, and it is not used for conducting self-assessment[41,42]. Further contrasts are found with benchmarking, SWOT, kaizen, policy deployment, and project management & control, as knowledge of CE is not automatically provided. As part of a benchmarking exercise this knowledge has to be sought for and understood by visiting best practice companies; this requires a lot of preparation in establishing the research question and data collection methods. Self-assessment, operational audits and workbook change management tools on the other hand already provide this knowledge and therefore a **'no'** has been placed against benchmarking within table 3[30]. A SWOT analysis assumes that this knowledge is already known prior to its application and therefore a **'no'** has been placed within table 3. Finally, kaizen, policy deployment, and project management and control are different from the above in that they provide a process for enabling change and therefore a '**no**' has been placed within table 3[35,36,19].

- **Measure Current and Identify a Future CE State:** Self-assessment, operational audits, benchmarking, and SWOT can assist the organisation to measure its current and future state as table 3 illustrates[31,33,32] and therefore a '**yes**' has been placed in table 3. Self-assessment and auditing achieves this by identifying which pre-defined criteria representing best practice has or has not been satisfied by the company[31,33]. Benchmarking requires good practice to be identified as part of the exercise and a current and future state is established by comparing the current organisation against best practice and defining a target organisation[30]. SWOT can provide a current picture of the organisation and assist in identifying future improvement activities by understanding its strengths, weaknesses, opportunities and threats. Further contrasts are found with workbook change management tools. Workbook change management tools do not provide a facility for a current and future states to be established, only a target model is provided and therefore a '**no**' has been placed within table 3[41,42]. Finally, tools such as kaizen, policy deployment, and project management and control provide a process for change but do not provide a clear means for an organisation to undertake a gap analysis against CE and therefore a '**no**' has been placed within table 3[35,36,19].

- **Provides a Scoring System:** Self-assessment provides a method to score practice as table 3 illustrates, because its quantifies an organisation's current and future state, and enable a company's performance to be measured and therefore a '**yes**' has been placed within table 3[31]. However, these tools contrast from benchmarking, auditing, SWOT, policy deployment, kaizen, project management and control and workbook change management tools for the following reasons. Whereas self-assessment tools provide a method for scoring the organisation, benchmarking and auditing require a scoring method to be developed prior to the execution and therefore a **'no'** has been placed within table 3[32,33]. SWOT and workbook change management tools do not provide a scoring system to support a gap analysis and therefore a **'no'** has been placed within table 3[41,42]. Finally, tools such as kaizen, policy deployment, project management and control and workbook implementation tools further contrast, because their purpose is to guide the change process and a scoring system is not provided to assess CE and therefore a **'no'** has been placed within the box[35,36,19,41,42].

- **Easy to Apply:** Arguably self-assessment, SWOT, auditing, and work-book change management tools are all easy to apply and therefore a **'yes'** has been placed in table3. Self-assessment, operational audits, and workbook change management tools generally provide instructions and some training for the application to occur[31,32,41,42], and therefore can be beneficial to companies that do not have the resources to undertake benchmarking. Benchmarking, kaizen, policy deployment, and project management and control contrast further, because due to their generic and top level nature, they have to be tailored for a specific problem which requires expertise in that area and therefore a **'no'** has been placed in table 3[32,35,36,19].
- **Involves Everybody:** Self-assessment, Benchmarking, SWOT, Kaizen, policy deployment workbook change management tools and project management and control aim to involve a wide scope of people from within the organisation to motivate change (see point 5, section 3.2 for clarification) and therefore a **'yes'** has been placed within table 3[31,35,36,41,42]. However, each tool uses a breadth of

individuals in different ways. Self-assessment requires a facilitator and a breadth of individuals from across the organisation to collect information, and to assess each criterion for a current and future state to be defined[31]. SWOT requires a group of individuals from across the organisation to brainstorm and identify the company's Strengths, Weaknesses, Opportunities, and Threats. Kaizen is a continuous improvement philosophy, where the four phases of the Deming wheel, 'plan', 'do', 'check' and 'act' are used for driving improvement[32]. Kaizen is fully leveraged when a company forms quality circles for creating an environment of teamwork. Each quality circle consists of a complimentary group of individuals, who are responsible for finding and implementing a solution[35]. Policy deployment is a change technique for deploying organisational policies to the lowest levels of the organisation by using a cascading approach that aims to involve each layer of the organisation[36] (see section 3.1.7). Benchmarking can use a breadth of individuals for assessing the organisation. Workbook change management tools are tailored to a specific problem, where again teamwork is central to its execution[41,42]. Finally, project management and control can involve all levels of the organisation for change if planned and deployed correctly[19]. A contrast is found with operational audits as they do not aim to involve a breadth of individuals as a means for preparing change. Auditing is a tool, which is executed by an auditing department and the results are communicated to top management only and therefore auditing does not involve all levels of the organisation when preparing for change and therefore a **'no'** has been placed within table 3[33]. For this reason auditing is not seen as being complimentary to enabling change.

- **Identifies Key Phases for Change:** Kaizen, workbook change management tools and project management and control define key phases for executing a change program and therefore a **'yes'** has been placed within table 3[35,41,42,19]. However, they differ for a number of reasons. Both Kaizen and project management and control identify key phases from a generic perspective, and they require tailoring for a specific project[35,19]. Workbook change management tools on the other hand have been designed to address the implementation of a specific philosophy or practice[41,42]. Self-assessment, SWOT, benchmarking and operational audits further contrast, because they are tools which support the change process by enabling a company to understand 'where it is now' and 'where does it want to go', but not 'how it will get there' therefore a **'no'** has been placed within table 3[31,32,33]. Finally, policy deployment does not provide a process for change but it compliments this process by providing a means for deploying company policies to the lowest level of the organisation and therefore a **'no'** has been placed within table 3[36].

Clearly, there isn't any one tool that addresses all the criteria defined for implementing CE. However, an integrated approach combining both self-assessment and a workbook change management tool is arguably the best combination for implementing CE. Potentially this system could address all criterion stated in section 3.2 by providing knowledge of CE, a scoring methodology, being easy to apply, involving everybody and identifying key phases for change. Therefore, the development of an integrated approach could provide greater benefits to organisations who want to implement CE and improve N.P.I. as the system would be able to assist them to measure, plan and control change toward CE.

3.3 Critique of Current Self-Assessment Tools and Workbooks

A number of self-assessment and workbook change management tools already exist within the literature, and before an integrated system could be developed, it was necessary to critically review these solutions as a means for identifying strengths and weaknesses and potential areas for innovation. The critique of these available tools was documented in detail within Submissions One and Five respectively.

3.3.1) Current Self-Assessment Tools: Arguably self-assessment was brought to the forefront by the National Quality Awards, these being the 'Malcom Balbridge Award', the 'European Business Excellence Model', and the 'Deming Prize'[45]. These tools were originally developed for encouraging Total Quality Management (TQM) by assessing its standard within an organisation, and rewarding the best company with a prize. Nevertheless, through this process, the potential for using self-assessment as a means for leveraging TQM was realised, and since then a number of organisations have been using it for directing quality endeavours.

Self-Assessment Tool	Description
Successful Product Development[46]	A self-assessment tool, which measures maturity in product development practice using a gap analysis. Its main components are product development strategy, structured product development process, teamwork, tools & techniques, working in parallel, and project and programme management.
Time to Market Association[47]	This provides guidelines for undertaking self-assessment, but it is not a self-assessment tool. The booklet provides a suggested maturity scale and a set of components for undertaking a potential assessment. These are product strategy, technology management, cross-functional teams, high level teams, reviews, process maps, metrics, re-use, functional excellence, and partnerships. The system does not provide a complete methodology for scoring and undertaking an assessment; it expects you as the user to develop this.
A Technical Innovation Audit[48]	A self-assessment tool, which measures maturity in aspects of the innovation process using a gap analysis. Its main components are product development, concept generation, leadership process, process innovation, resourcing process, technology acquisition, and systems and tool.
Readiness Assessment for Concurrent Engineering[49]	A self-assessment tool, which measures maturity in concurrent engineering using a gap analysis. This system has two main components a process dimension and a technology dimension. The main components of the process dimension are customer focus, product assurance, leadership, team formation, agility, teams in organisation, process focus, management systems, and discipline.
Mentor Graphics Self-Assessment Tool[1]	A self-assessment tool, which measures maturity in concurrent engineering using a gap analysis. Its main components are communication infrastructure, organisation, product development, and requirements.

Table 4 A Summary of Available Self-Assessment Tools

Self-assessment tools have also emerged for measuring the deployment of CE, and identifying areas for improvement as described in table 4. In total five different self-assessment tools were found, which aim to either assess CE, or the innovation process. In all cases they aim to measure an organisation's current state against best practice, and provide a means to identify future improvements.

To develop an understanding of the strengths and weaknesses of each tool a critical review was undertaken by the R.E. Each tool was assessed as to whether they:

1) Paid enough attention to CE design philosophies such as design for manufacture & assembly, design for cost, design for serviceability, design for reliability and design for customer requirements as these were recognised as critical philosophies of CE[2].
2) Considered both a practice and performance dimension; this is essential to ensure that practices implemented are delivering to the bottom line[45].
3) Could be tailored to an industry's specific needs rather than assuming one set of criteria for all organisations[50].
4) Have an implementation methodology?
5) Have any additional attributes, which enhanced or inhibited the ability of the tool to assess or implement CE?

These criteria were used, because the R.E. wanted to critique the current available tools for assessing CE in greater detail than the previous analysis introduced in section 3.2. Furthermore, they were identified as potential weak areas by the R.E.. A summary of the strengths and weaknesses are presented within table 5, which illustrates a number of gaps.

Tools	Strengths	Weaknesses
Successful Product Development[46]	▪ Considers Strategic and Operational Factors	▪ Subjective Lacks Robustness ▪ Poor Implementation Method ▪ Lacks Performance Metrics ▪ Assumes One Model for All ▪ Not Enough Emphasis on CE
Time to Market Association[47]	▪ Provides Education Aids ▪ Implementation Route Maps	▪ Not a Self-Assessment Tool ▪ Not Enough Emphasis on CE ▪ Lacks Performance Metrics ▪ Provides One Model for All
A Technical Innovation Audit[48]	▪ Includes Performance Metrics	▪ Not Enough Emphasis on CE ▪ Assumes One Model for All ▪ Lack of Validation ▪ Lacks an Implementation Approach
Readiness Assessment for Concurrent Engineering[49]	▪ Considers Strategic and Operational Factors	▪ Assumes One Model for All ▪ Lacks Performance Metrics ▪ Lacks an Implementation an Approach ▪ Does not Provide Solutions ▪ Not Enough Emphasis on CE
Mentor Graphics Self-Assessment Tool[1]		▪ Not Enough Emphasis on CE ▪ Lacks Performance Metrics ▪ A Subjective Means for Deciding the Future State ▪ Not Enough Depth ▪ Assumes One Model for All ▪ Does Not Provide an Implementation Process

Table 5 Strengths and Weaknesses of Self-Assessment Tools

- Current self-assessment tools measure *'where are we now?'* and *'where do we want to go?'* However, they do not provide an aid for facilitating implementation. This provides an opportunity for developing a tool, which assesses and deploys CE practice.
- The tools assume one model for all organisations. They do not provide an opportunity for tailoring a model for an organisation's specific circumstances.
- Each self-assessment tool does not pay enough attention to the application of CE from the perspective of achieving specific design philosophies such as design for manufacture, service, reliability, customer requirements and cost.
- Finally, each self-assessment tool does not put enough emphasis upon performance metrics as a means for ascertaining whether improvements are delivering to the bottom line. A technical innovation audit does address this issue, but practices have not been linked to achieving specific results.

3.3.2) Current Workbook Change Management Tools for Implementing CE:

Two workbook change management tools exist within the literature that have been designed specifically for implementing CE through using a project management and control related approach. These tools are PACE [40, 41] and the Cranfield approach[42]. As previously stated, the purpose of these was to provide UK organisations with the means to leverage CE practice by a 'do it yourself method' rather than using expensive alternatives such as consultants or embarking on a major benchmarking exercise. Therefore, each change process will be introduced.

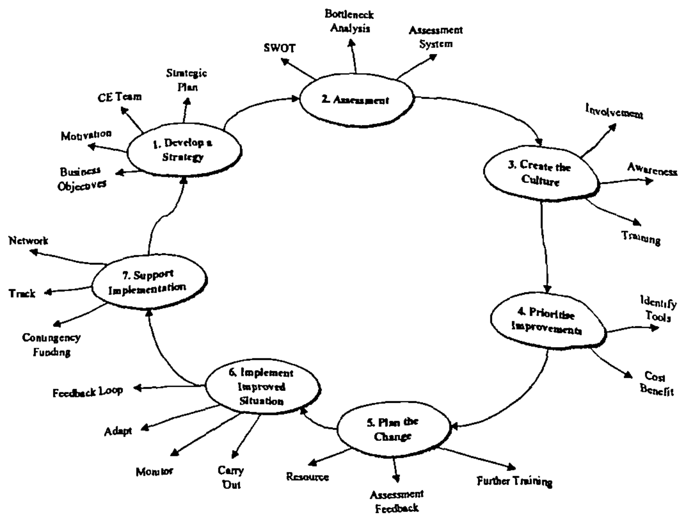

Figure 5 A Generic Framework for Implementing CE[40,41]

As figure 5 illustrates, PACE consists of seven phases; 'develop a strategy', 'assessment', 'create the culture', 'prioritise improvements', 'plan the change', 'implement improved situation', and finally 'support implementation'. Each phase will be briefly discussed [40, 41].

- Develop a strategy requires top management to formulate a strategy as a means for creating a sense of urgency that change is required.

- The assessment phase requires the organisation to understand its current state by assessing resources and tools.
- Create the culture requires the work force to understand the need for change.
- Prioritise improvements requires the organisation to select which practices are the most important to the organisation.
- Plan the change requires the pre-preparation work to be translated into plans for implementation.
- Implement improved situation requires the plans developed from the previous stage to be deployed.
- Finally, support implementation requires commitment from senior management.

Cranfield's approach to implementing CE uses a prescribed work-book tool, which consists of three main phases: 'prepare', 'implement', and 'extend' as figure 6 illustrates[40]. Furthermore, this tool adopts a pilot approach followed by company wide implementation for deploying practices, and therefore is mainly targeted at first time adopters of CE. Each phase of the process will be briefly explained.

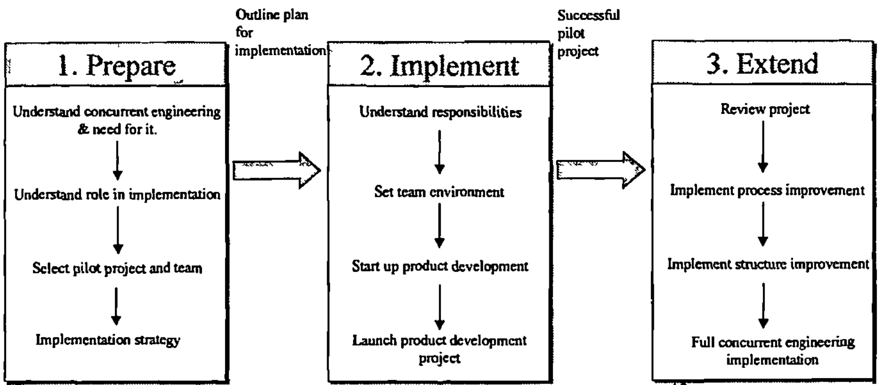

Figure 6 Cranfields Implementation Process for CE[42]

- The first phase 'prepare' aims to focus the company towards implementing CE. This phase is started with a two day workshop, which aims to focus senior managements attention towards the basics of CE and its needs. Therefore, within this phase requirements for enabling CE are determined.
- The second phase 'implement' is aimed at planning and implementing new practices using a pilot approach for executing product development. During this phase management assign roles and responsibilities, develop the project plan, and implement the project.
- Once the pilot approach has been completed, the third phase 'extend' aims to prepare the company for full organisational implementation. This requires elements of the pilot project which were successful, to be identified and a plan of action to be agreed.

To identify the strengths and weaknesses, the R.E. assessed each tool with the following criteria in mind.

1) Did the workbook change management tool include self-assessment?
2) Had the workbook been validated?
3) Was the workbook well prescribed and useable?
4) Did the workbook take into account different implementation strategies such as an incremental or a big bang approach to implementation.
5) Any additional attributes which enhanced or inhibited the tool to implement CE.

Again these criteria were used because the R.E. wanted to review the workbooks in greater detail than the previous analysis conducted in section 3.2 so that opportunities for improvement could be identified. Therefore, the strengths and weaknesses observed are presented within table 6, which resulted in the following gaps.

Tools	Strengths	Weaknesses
PACE Implementation Tool[40,41]	▪ Takes different implementation strategies into account.	▪ Not well prescribed resulting in a lack of depth. ▪ Lack of Validation ▪ Does not Include Self-Assessment
Cranfields Implementation Tool[42]	▪ Well Prescribed ▪ Has Been Demonstrated	▪ Targeted to First Time Adopters ▪ Only Uses the Pilot as an Implementation Strategy ▪ Does not Include Self-Assessment

Table 6 Strengths and Weaknesses of Workbook Change Management Tools

- The PACE workbook to implementation can be described as superficial as its process is only prescribed at a top level. Furthermore, this tool has not been tested within an industrial context. Therefore it is difficult to assess whether it can drive an improvement program.
- The Cranfield workbook is well prescribed, but it only uses the pilot approach as a means for deploying practice before company wide implementation. Therefore, it does not take into account whether an organisation wants to use a radical approach to implementation under the circumstances of a crisis. Furthermore, this tool is targeted toward first time users rather than organisations that are relatively mature in its application and are looking for areas that require improvements.

3.4 Requirements for a New Tool

Based on these findings a new set of requirements was defined within submissions one and five respectively, for a self-assessment tool integrated with a change management process. Each will be presented.

1. *Define a self-assessment tool encapsulating the accepted CE practices of UK industry. This will provide organisations with the means to measure themselves against national practice.*

Current practices deployed within self-assessment tools are based upon what is considered best practice by the literature, but they do not provide an indication of whether they have been adopted by industry. By providing a self-assessment tool with practices based on UK organisations, knowledge of CE will be provided so that companies can compare their practices against those already deployed by industry.

2. *Be tailored to take into consideration industry specific needs.*

The previous self-assessment tools assume one model for all organisations. The ability to tailor CE knowledge will enable an organisation to select and assess itself against practices that is specific to its needs.

3. *Provide an in-depth means for assessing the current state of CE practices by reviewing both the deployment and application of components.*

The previous self-assessment tools only assess the deployment of practices, but not how they are executed in the context of a CE program. Arguably the success of a project is dependent upon how practices are executed to achieve specific design philosophies.

4. *Provide a company with the means to strategically plan and identify areas which can be improved through using a result driven process.*

The principle of using a result driven process is based upon a paper titled *'Successful Change Programs Begin with Results'*, where change programs should be targeted for achieving specific measurable results to the bottom line[51]. Current self-assessment tools provide scoring methods, which primarily concentrate upon practices but not performance.

5. *A system, which can be easily applied by knowledgeable practitioners in the field of product development.*

It is essential that the tool is useable and easy to apply during the course of a change program.

6. *Integrate a self-assessment tool with a workbook change management process.*

The self-assessment and workbook change management tools reviewed were not integrated; they acted as disparate tools. An integrated approach arguably would provide the benefits of being able to assess and provide a gap analysis, and identify key phases for enabling change.

7. *Provide an organisation with the flexibility to choose an incremental approach or a radical approach to implementation.*

Arguably the pace of change is dependent upon the industry sector conditions, which an organisation operates within, and therefore the pace of change required may differ. Current tools for enabling the implementation of CE do not provide any rule-base for deciding whether to take an incremental or a radical approach to change.

8. *Provide a process, which is well prescribed and will allow a facilitator to direct a change program.*

Providing a process for guiding change will enable a facilitator to be appointed who can pro-actively plan and deploy a change program.

3.5 Summary

This chapter presented a review of how a self-assessment tool integrated with a change management process was selected to provide a solution for implementing CE within UK industry. In addition, requirements for a new system were defined. These were based upon a critique of previous self-assessment tools and workbook change management tools identified within the literature.

Chapter 4 Developing the Models

4.0 Introduction

To develop the self-assessment tool integrated with a change management process for implementing CE and improving N.P.I., two models of practice were developed for the following reasons. Currently, an assessment tool does not exist which represents accepted industry practice, and the existing work-book change management tools were designed to be standalone. Therefore, this chapter will present how each model was defined and verified.

4.1 Developing a Model of Concurrent Engineering Practice

To execute self-assessment, a model of good CE practice is required, which provides a basis for assessing the organisation[52]. To define a model, which encapsulated the practices of British Industry, a conceptual model based on the literature was developed by the R.E. as illustrated in table 7, and was reported within submission two. The model is configured by six main components: a formal N.P.I. process, teamwork, information technology, tools and techniques, supply chain management, and project management. A definition for each can be found in chapter 1. Furthermore, it can be observed that each component breaks down into a series of parts, and a detailed description of these can be read in Submission Two.

Component	Parts
Formal N.P.I. Process	▪ Phases of Product Development ▪ Review and Checklists ▪ Concurrency Built into the Process ▪ Defined to Different Levels of Detail ▪ Used as a Basis for Planning Projects ▪ Used as a means for guiding N.P.I. Activities
Teamwork	▪ Multifunctional teams ▪ Team Leader ▪ Functional Skills ▪ Empowered Decision Making ▪ Cross-Functional Communication ▪ Accountability ▪ Team Structure
Information Technology	▪ Electronic Product Definition ▪ Product Data Management ▪ Networking ▪ Video Conferencing
Tools & Techniques	▪ Quality Function Deployment ▪ Design for Manufacture ▪ Failure Mode & Effects Analysis ▪ Taguchi ▪ Rapid Prototyping
Supply Chain Management	▪ Supplier Selection Procedures ▪ Electronic Data Transfer ▪ Involving Suppliers within the Team ▪ Simple Tiered Structures
Project Management	▪ Feasibility Study ▪ Project Specification ▪ Project Complexity Reduction ▪ Project Planning ▪ The Use of Historical Time Data ▪ Project Reviews ▪ Project Evaluation ▪ Project Documentation

Table 7 Conceptual Model of CE Practice Defined Using the Literature

4.1.1) Survey of UK Industry: To gain some feel of whether the conceptual model was representative of UK industry, a survey was undertaken that assessed whether UK companies utilised CE practices identified in the literature. The hypothesis were measured as stated within the research methodology, chapter 2, section 2.2.2. and the analysis was reported within submission three. Table 8 illustrates that correlations were found between practices utilised and concurrency; this supported the requirements for a *'formal N.P.I. process'*, *'teamwork'*, *'tools & techniques'* and *'supply chain management'* for executing CE as the practices tested agreed with the hypothesis proposed to a 5% level of significance. However, there were a number of practices that were identified within the literature to be essential for the successful execution of CE, but were found to not support the hypothesis. These were within the domain of *'information technology'* with practices such as CAD and exchange standards, and *'project management'* with practices such as the utilisation of a project specification and a project budget assessment not supporting the hypothesis. However, these results must be questioned, as their importance is clearly stated within the literature. Therefore, to investigate these issues further, a case study analysis was undertaken.

Practices	Supports Hypothesis	Significance Level
FORMAL N.P.I. PROCESS		
Formal N.P.I Process	Yes	5%
TEAMWORK		
Multifunctional Teams	Yes	5%
Project Owner	Yes	5%
Cross-functional Skills	Yes	Did Not Apply
Co-location	No	5%
Cross-functional Communication	Yes	Did Not Apply
INFORMATION TECHNOLOGY		
CAD	Not Supporting	-
CAM	Yes	5%
Data Base Systems	Yes	5%
Exchange Standards	Not Supporting	-
Networking	Yes	5%
TOOLS & TECHNIQUES		
Quality Function Deployment	Yes	5%
Design for Manufacture	Yes	5%
Failure Mode & Effects Analysis	Yes	5%
Rapid Prototyping	Yes	5%
SUPPLY CHAIN MANAGEMENT		
Integration within Teams	Yes	5%
Early Supplier Inclusion	Yes	5%
Open Relationships	Yes	5%
PROJECT MANAGEMENT		
Project Specification	Not Supporting	-
Project Planning	Yes	5%
Project Budget Assessment	Not Supporting	-
Risk Assessment	Yes	5%

Table 8 A Summary of the Survey of UK Industry

4.1.2) Verifying the Conceptual Model: Submission Five reports an investigation, which aimed to compare the theoretical model against eight case study companies representing the aerospace, automobile, power generation, and electrical/mechanical industry sectors. The results are shown within table 9.

*	Correlations Present	
-	No Correlation Present	
N/K	Not Known	

	High Complexity				Low Complexity			
	Rolls Royce	Alstom	Rover/BMW	Airbus	Lucas	Parker	Integrated Design	Howe LTD
Formal N.P.I. Process								
Formal New Product Introduction Process	*	*	*	*	*	-	-	*
Phases of Product Development	*	*	*	*	*	-	-	*
Reviews with Checklists	*	*	*	*	*	-	-	*
Concurrency Built into the Process	*	*	*	*	*	-	-	-
Defined to Different Levels of Detail	*	*	*	*	*	-	-	-
Used as a Basis for Planning Projects	*	*	*	*	*	-	-	*
	*	*	*	*	*	-	-	*
Teamwork								
Multifunctional Teams	*	*	*	*	*	*	*	*
Team Leader	*	*	*	*	*	*	*	*
Functional Skills	*	*	*	*	*	*	*	*
Empowed Decision Making	*	*	*	*	*	*	*	*
Cross Functional Communication	*	*	*	*	*	*	*	*
Accountability	*	*	*	*	*	*	*	*
Co-location	-	*	*	*	-	-	-	-
Team Structure	*	*	*	*	*	*	*	*
Information Technology								
Electronic Product Definition	*	*	*	*	-	*	-	-
Product Data Management	*	*	*	*	-	-	-	-
Networking	*	*	*	*	*	*	*	*
Video Conferencing	N/K	*	*	*	*	*	-	-
Tools & Techniques								
Quality Function Deployment	N/K	*	*	-	*	-	-	-
Design for Manufacture	N/K	-	*	-	*	-	-	-
Failure Mode & Effects Analysis	N/K	*	*	*	*	*	*	*
Taguchi	N/K	*	-	-	-	-	-	-
Rapid Prototyping	N/K	*	*	*	*	*	-	-
Supply Chain Management								
Supplier Selection Procedures	N/K	*	*	*	*	*	*	-
Electronic Data Transfer	N/K	*	*	*	*	-	-	-
Involving Suppliers within the Team	N/K	*	*	*	*	*	-	-
Simple Tiered Structures	N/K	*	*	*	*	-	-	-
Project Management								
Feasibility Study	*	*	*	*	*	*	*	*
Project Specification	*	*	*	*	*	*	*	*
Project Complexity Reduction	*	*	*	*	*	*	-	-
Project Planning	*	*	*	*	*	*	*	*
The Use of Historical Time Data	*	*	*	*	*	*	*	*
Project Reviews	*	*	*	*	*	*	*	*
Project Evaluation	-	-	-	-	*	*	-	-
Project Documentation	-	-	-	-	*	*	-	-

Table 9 Summarised Results of the Agreements between the Conceptual Model and the Case Study Companies

The stars allocated in the boxes demonstrate that correlations were found between the model and each company. This offered further evidence that the model of CE practice was representative. However, the use of practices was not found to be consistent in all cases. The reasons for this could be attributed to the following.

- It was found that organisations who developed complex products had a greater requirement for a *'formal N.P.I. process'*, the practice of *'electronic product definition'* and *'product data management'*, than organisations that developed non-complex products. The reason for this may be due to these organisations having to manage greater quantities of data, thus requiring these tools to manage information.
- The use of some tools and techniques was also found to be low within a number of case study companies. This was generally attributed to companies not yet realising their benefits. However, in the case of *'design for manufacture'*, certain companies believed that this tool would only benefit those companies which produced products with long production runs. This implied that the tool would not provide a large payback for products that are of a bespoke nature.
- Finally, agreements were not always found to support supply chain management practices such as *'electronic data transfer'*, and *'simple tiered structures'*. Nevertheless, this was attributed to companies not realising their benefit or that they were 2nd tier suppliers, where they only had a small number of suppliers to manage.

4.2 Development of the Change Management Process Model

To enable change toward CE, a change management process model was also developed as figure 7 demonstrates, which can be integrated with a self-assessment tool. This consists of ten main phases, which can be grouped under the following headings *'Where are we now?' 'Where do we want to go?' 'Plan for Implementation'* and *'Deploy'*. This was reported within Submission Five.

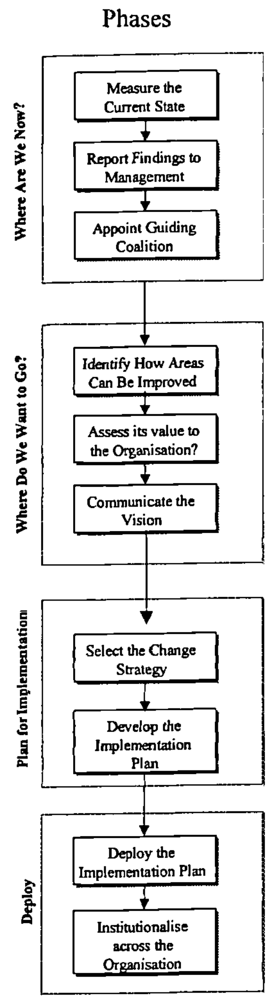

Figure 7 A Change Management Process Model for Implementing CE

To develop this process, a literature review of previous models was undertaken. Three models were identified, these were Kotter[23], Cummins and Worley[37], and Bullocks and Batten[38]. Kotter's model was used because although it contained the same basic phases as other models, they were encapsulated in greater detail by defining the requirements for change with more phases. Bullocks and Battens model was selected, because their model is based on thirty previously developed change models. Finally Cummins and Worleys model was used so that an additional perspective would be given from the previous two models. Therefore, it was felt that using these three would be representative.

4.2.1) Comparison of the Change Model against Two Case Study Companies: To verify the change management process model developed, the R.E. used case studies describing how Lucas/Varity and Rover Group undertook change toward competitive product development. In both cases they were implementing a formal new product introduction process, which required a business process re-engineering and an organisational re-design approach.

As table 10 reports, the theoretical change management process model compared in many areas with both case study companies. Both companies:

- Established their current state by either benchmarking or reviewing a number of performance measures.
- Reported their findings to senior management.
- Appointed a guiding coalition for driving the change.
- Identified how areas can be improved.
- Communicated the vision to other members of the organisation.
- Selected a change strategy of how to deploy the new working practices.
- Developed an implementation plan.
- Used the implementation plan as a basis for guiding change activities.
- Used systems standards and audits as a means for institutionalising new practices.

These activities supported the change management process model.

Mode I Steps	Comparison
Measure the Current State	The model developed states that to achieve a sense of urgency, the organisation requires both practice and performance measures to be assessed for defining its current state by using self-assessment. This approach compared with the practices of Lucas and Rover who measured their current state through benchmarking and performance measures respectively, but this was not achieved through using self-assessment.
Report Findings to Management	The model developed states that once the current state has been established; it is necessary to communicate to management that change is required. At Lucas and Rover, the current state of the organisation was communicated to executives and senior management as a means to develop a sense of urgency that change is required.
Appoint Guiding Coalition	The change model developed states that a powerful guiding coalition should be appointed, which consists of the CEO and top management who would be responsible for guiding activities. This compared with Lucas who appointed a steering group, which consisted of technical directors and senior management, and Rover who appointed a heavyweight management team for driving change. In both cases the CEO was not directly involved, but they approved the process.
Identify How Areas Can Be Improved	To identify how areas can be improved, the current state of the organisation established in 'measure the current state' should be used to identify weakness areas, and therefore provide a basis for establishing future objectives using a result driven process. Evidence was found to support that both Lucas and Rover created a set of future objectives to solve their current problems. However, in the case of Lucas they used the results of their benchmarking exercise as a basis to establish their future objectives, whilst Rover used Delphi consensus techniques to develop its vision.
Assess its Value to the Organisation	Once a number of areas have been targeted for improvement, the model states that its potential benefits should be assessed. However, it is not clear from the case studies how Lucas or Rover executed this phase.
Communicating the Vision	To communicate the vision the model developed proposes that the guiding coalition communicates the solution to the rest of the organisation, and change agents should be elected to support change. Lucas communicated the vision via executive workshops, and these individuals in turn were responsible for communicating the vision to the working level. Rover on the other hand communicated the vision via the heavyweight management group and change managers. Therefore, both cases support the model.
Select the Change Strategy	The model requires a change strategy to be decided, these being either a big bang approach or an incremental approach. In the case of Lucas, they elected for a big bang approach where PIM was rolled out across all projects that were deemed to be suitable. However, at Rover their approach was more in line with an incremental strategy where improvements were rolled out over a five-year time period. Nevertheless, both companies undertook the process of selecting a change strategy and therefore it supports the model.
Develop the Implementation Plan	The change model requires a timing plan to be developed proposing key phases and milestones of the deployment process. Both Lucas and Rover developed a timing plan for implementation that stated key milestones for the delivery process.
Deploy the Implementation Plan	The change model states that the plan is to be used as a basis for guiding the deployment of practices. This compared with Lucas and Rover as they used their timing plans as a basis for directing change activities.
Institutionalise New Working Practices	To institutionalise new working practices the model developed proposes that the new way of working is documented within system standards. Furthermore, too regularly assess the organisation to ensure that practices are conforming to standards. Evidence was found to support this activity at Lucas and Rover as they also documented their processes within systems standards and they used auditing as a means to institutionalise practices across the organisation.

Table 10 Comparisons between the Conceptual Model and the Case Study Companies

However, there were key differences between the model and the case study companies. The theoretical change model uses self-assessment for establishing a sense of urgency and creating a future vision. This differed from Lucas, as they reported that they undertook a series of benchmarking visits to other known good practice companies. Rover meanwhile measured a series of performance measures, which were related to product introduction lead-time, warranty data, and market share. Furthermore, to develop a future desired state, Lucas again used the benchmarking visits to establish the solutions, and Rover used a Delphi consensus technique. Therefore, the self-assessment tool provides an alternative to these activities.

4.3 Summary

Two theoretical models and their development were presented. Each model was introduced explaining how they were developed and verified against industry practice. These models will provide a basis for developing a self-assessment tool integrated with a change management process. Therefore, within the next chapter an integrated approach to assessing and implementing CE will be reported.

Chapter 5 Defining an Integrated Approach for Deploying CE

5.0 Introduction

This chapter will report the system developed by the R.E. to provide an integrated approach to assessing and implementing CE practice within the organisation to improve N.P.I.. The tools adopted within the system can be broken down into two categories. Those which were developed specifically for the application, and those, which were selected from the literature. Furthermore, figure 8 presents the structure of the system, which can be categorised into four sections, *'self-assessment tools'*, *'planning tools'*, *'tools for deployment'* and the *'implementation process'*. These categories will provide the basis for introducing the system within the chapter.

Self Assessment Tools	Planning Tools	Tools for Deployment
•The Assessment Tool •The Tailoring Tool •The Scoring Matrix •The Strengths/Opportunities Matrix •The CE Component Selection Matrix •Risk Assessment •Forecasting	•Implementation Strategy Tool •A Generic Planning & Guidance Tool •Project Structure Breakdown •GanntCharts •Resource Histograms •Budget Planning Tools •Project Matrix Structure	•Teamwork •Process Mapping Tools •OrganisationalRedesign Tools •Benchmarking •Training •Systems Standards

The Change Management Process

Figure 8 A System for Assessing and Implementing CE

5.1 Introduction to the Self-Assessment Tools

5.1.1) The Assessment Tool: The assessment tool was developed to provide an organisation with the opportunity to assess its performance and practice against specific sectors of UK industry. Nine main components are assessed, which can be categorised within a practice or performance dimension as illustrated by figure 9. Practices which were embedded within the tool were built upon the components of CE established from British Industry, whilst performance metrics were based upon a literature review. The purpose of measuring both practice and performance was to ensure that operational improvements are delivered to the bottom line. Therefore, each component of the tool assesses:

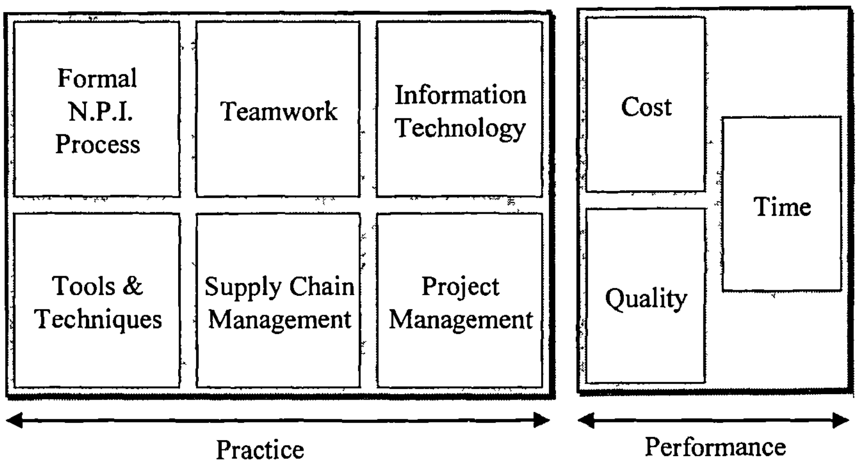

Figure 9 Framework for Assessment

- The definition of a formal N.P.I. process and how it is used within the context of a project.
- The structure of the team and how the team operates within the context of a product development project to achieve design for manufacture, serviceability, test and customer requirements.
- The deployment of I.T. technologies for supporting CE and how they are deployed and utilised within the context of a project.
- The deployment of tools for supporting CE and how they are applied within the context of a project.

- Supply chain management techniques and how they are applied for supporting CE.
- Project management practices, and how they are executed for supporting CE.
- Whether the product development project is delivered to product cost and project budget.
- Whether the project meets key milestones set within the project plan, and whether the overall product development project is delivered on time.
- Whether the development project meets its quality targets.

Categories

Parallel Activities Only	
17	*Design Engineers Execute Work Packages Concurrently With Down Stream Work Packages.*
Design for Customer Requirements Only (See Sub 4, Chap5)	
18	*Cross Functional Problem Solves Design Issues With Marketing At The Early Phases Of The Process (See Sub 2, Section 2.2.7 and Sub 4, Section 4.2.5 and Section 5.5)*
Design for Manufacture Only (See Sub 4, Chap 5)	
19	*Cross Functional Problem Solves Design Issues with Manufacturing at the Early Phases Of The Process (See Sub 2, Section 2.2.7, and Sub 4, Section 4.2.5 and section 5.2)*

Figure 10 Example of Categorised Assessment Criteria

For each component, the overall criteria for assessment and the requirements for consistency that have to be addressed are defined and reported within appendix 1. Therefore the tool is structured at three levels. Level 1 defines the *'component level'* as illustrated by figure 9. Level 2 defines the criteria for *'practice and performance'* for each component. Finally, level 3 defines the *'requirements for consistency'* for each criterion to ensure a consistent assessment. In addition, to understand what criteria addresses the application of design philosophies such as design for manufacture, serviceability, cost, customer requirements and reliability, each was categorised under one of these labels as illustrated by figure 10. The purpose of this is to assist the user to select criteria based on the philosophies that he wants to execute.

5.1.2) Tailoring the Assessment Tool: The assessment tool can be tailored for an organisation's specific requirement. Figure 11 presents the tailoring tool developed by the R.E. for selecting criteria when preparing for an assessment exercise. This tool aims to link the selection of criteria with strategy and customer requirements, and its approach is based upon principles defined by Porter, which are explained within submission six[7].

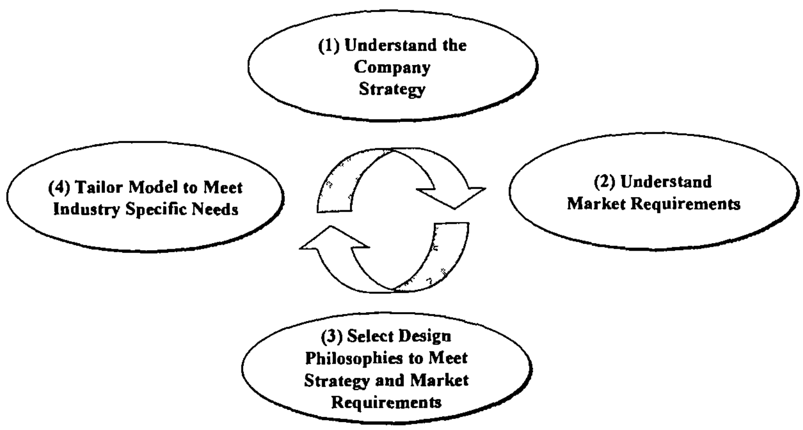

Figure 11 Tailoring Process Tool

- The first phase of the process *'understand the company strategy'* requires the selection of one of three generic strategies as defined by Porter[7]. *'A cost leadership strategy'*, a *'differentiation strategy'*, and a *'cost focus strategy'*. Furthermore, in addition to supporting the generic strategies a timing strategy is also required, stating whether the company wants to be a first mover or a market follower.
- The second phase *'understand market requirements'* requires the organisation to understand what factors are important to the needs of its specific targeted

customers with respect to cost and quality. By understanding their requirements, a model of practice can be prescribed.

- The third phase *'select relevant design philosophies to meet strategy & market requirements'* requires the organisation to select specific design philosophies such as design for manufacture, which will impact strategy and market requirements.
- Finally, the last phase of the process *'tailor model to meet industry specific needs'* requires specific criterion to be selected from the criteria, which are relevant to achieving the specified design philosophies.

	Time	Cost	Quality
Parallel Activities	**Reduce**		
Design for Manufacture	**Reduce**	**Reduce**	
Design to Cost		**Control**	
Design for Reliability			**Increase**
Design for Customer Requirements			**Increase**
Design for Serviceability		**Increase**	**Increase**

Figure 12 Design Philosophies Matrix Demonstrating the Impact of Good Concurrent Engineering Principles upon Product Development Performance

To assist the user during the third phase of 'select relevant design philosophies to meet strategy & market requirements', a design philosophies matrix as shown by figure 12 was developed. The purpose of the matrix is to state which design philosophies impact project performance so that they can be prioritised. An explanation of why the relationships between design philosophies and performance measures exist will be given.

- Parallel activities require design and manufacturing activities to be executed in parallel rather than sequentially. Concurrent activities result in product development lead-times being compressed, which impacts time[4].
- Design for manufacture (DFM) requires manufacturing issues to be considered at the design phase[6]. DFM considers issues such as designing for process capability, and optimising the number of components that configure a product so that the number of sequences within a manufacturing build process can be minimised[6,53]. DFM impacts time, because design induced mistakes, which are discovered during the manufacturing build process do not have to be rectified. Moreover, a reduction in the number of components reduces the total cost of manufacturing a product[53].
- Design to cost requires the product to be designed and delivered to a known set of cost targets and therefore impacts cost[53]. By controlling product costs, it allows a company to sell a product at a set market price, and ensure that profit margins are maintained.
- Design for reliability aims to optimise the reliability of a product by ensuring that reliability targets set within the specification are met. A definition of quality is *'conformance to customer requirements'*[54], and therefore the execution of a design for reliability philosophy can enhance and improve quality.
- Design for customer requirements aims to ensure that customer wants and needs are encapsulated within the product[2]. If this is achieved, arguably the product is conforming to customer requirements, and therefore the execution of a design for customer requirements philosophy can enhance and improve quality.
- Finally, design for serviceability aims to capture a customer's serviceability needs and design a product, which meets these requirements[2]. If this is achieved, then

arguably a product is again conforming to customer requirements, and therefore the execution of such a philosophy can improve quality.

5.1.3) Assessing the Current State: To assess the current state, it is necessary to evaluate the criteria and requirements for consistency as defined within appendix 1 against the organisation. A tool developed by the R.E. to assist this activity was the scoring matrix as shown in figure 13. This was based upon the assessment method used by the European Business Excellence Model[45]. To assess the criteria, the matrix is applied to assign a score of zero, one, two or three for each criterion by assessing whether none, less than half, more than half or all the requirements for consistency specified for that criterion is found within the organisation.

Reference No	Assessment Methods	Requirements for Consistency
Reference 1	▪ Formal N.P.I Process	▪ Phases of Product Development ▪ Stage Gate Methodology
Reference 2	▪ Formal N.P I Process ▪ Interview Project Manager Quality Manager	Definition of concept design activities such as: ▪ Capturing customer requirements ▪ Product planning ▪ Definition of the product specification ▪ Project Plans ▪ Resources ▪ Budgets ▪ Initial concept definition ▪ Definition of initial bill of materials ▪ Definition of initial prototype ▪ Demonstration of new technologies ▪ Identification of critical suppliers

Non of the requirements for consistency have been deployed.	Less than half of the requirements for consistency have been deployed.	More than half of the requirements for consistency have been deployed.	All of the requirements for consistency have been deployed.
(0)	(1)	(2)	(3)

Figure 13 Scoring the Criteria with the Scoring Matrix

To calculate an overall score, a minimum of zero and a maximum of one hundred can be allocated to each component of the self-assessment tool by summing the total score for each criterion and normalising it to a scale of 0-100. A spider diagram is defined as illustrated by figure 14, which represents the organisations current state. This demonstrates for example that for teamwork a total score of forty was given.

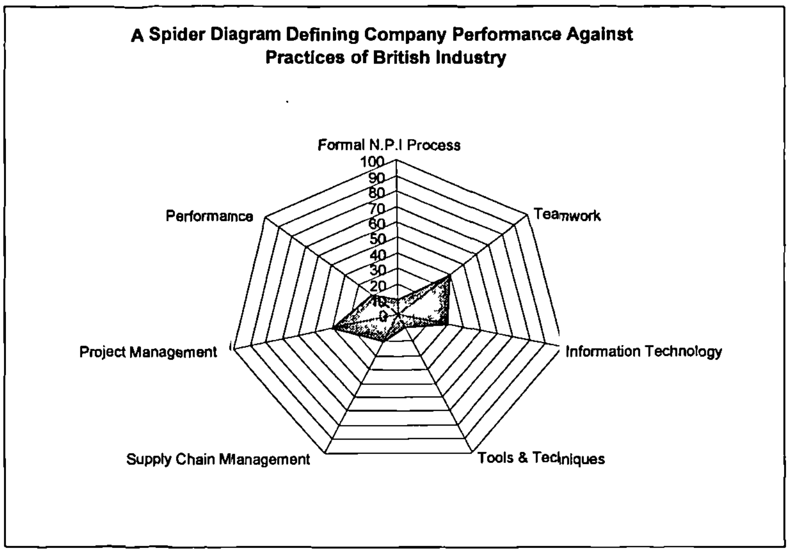

Figure 14 Example of a Spider Diagram Representing a Benchmark Profile

To establish a company's maturity, it is necessary to translate the benchmark score into a maturity level for both practice and performance. This process of measuring maturity was based upon the methodology used by RACE[49]. The performance dimension consists of four main phases as shown by table 11, these are a non-performer phase, an early maturity performer phase, a late maturity performer phase, and a mature performer phase. The practice dimension consists of five phases as shown in table 12, these are a non-developing phase, an early developer phase, a late developer phase, a consistent developer phase, and finally an optimiser phase. Therefore, to assign a maturity level for each component the user has to take the total score for that component, and use the flow diagram located in appendix 2 for defining a maturity level.

Maturity Phase	Definition
A None Performer	Project(s) fail to deliver a new product to meet any of the performance criteria.
An Early Maturity Performer	Project(s) deliver a new product, which meet a limited set of performance criteria.
A Late Maturity Performer	Project(s) deliver a new product, which meet the majority of performance criteria.
A Mature Performer	Project(s) deliver a new product to meet all performance criteria.

Table 11 Performance Maturity Criteria

Maturity Phase	Definition
Non Developing	Project(s) does not utilise any good practice tools and methodologies for executing concurrent engineering.
Early Developer	Project(s) apply some good practice tools and methodologies for enabling efficient concurrent engineering.
Late Developer	Project(s) apply most good practice tools and methodologies for enabling efficient concurrent engineering.
Consistent Performer	Project(s) apply all good practice tools and methodologies as a means for achieving concurrent engineering.
Optimiser	Project(s) apply all good practice tools and methodologies and continuous improvement methods.

Table 12 Practice Maturity Criteria

Finally, to support the spider diagram, and the company's maturity profile, it is necessary to report the strengths and weaknesses identified for the practice and deployment of each component. This is to be grouped and reported through using the strengths/opportunities matrix. Again this adopts the approach used by the European Excellence Model[43].

5.1.4) Deciding the Future State: To establish a future desired state it is necessary to understand whether the components of CE and embedded practices are relevant to the organisation. This requires desired practices to be defined, which will provide the required competitive advantage.

To undertake this process, table 13 was developed by the R.E. from the literature. The table states the purpose of each component, and in what circumstances they are to be used as a means for selecting a set of top level components. Once a set of components have been selected, it is then necessary to define a specific set of criteria for each component of the assessment tool, which will impact time, cost, budget and quality. This is achieved by understanding which performance measures are of priority, and selecting the relevant design philosophies such as a design for cost philosophy to impact cost. These decisions are assisted by using the design philosophies matrix tool introduced in figure 12. Finally, the desired state prescribed has to be translated into a future profile by assigning a 3 for each new criterion selected in addition to those found within the organisation. These are to be summed and normalised to a scale of 0-100 and plotted on the spider diagram for a future desired state to be defined.

Component	Purpose	Conditions for Use
Formal N.P.I Process	▪ To provide an N.P.I. route map[15]. ▪ To manage risk by stage gate management[55]. ▪ To capture and embed best practices[55]. ▪ To formalise product development practices[55].	▪ Managing complex projects with high capital investment[56]. ▪ Company is poor at meeting quality, cost and time targets. ▪ The company operates within unstable markets, requiring reactive product development lead-times. ▪ When different N.P.I. models are being used throughout the organisation.
Teamwork	▪ To enable concurrent engineering. ▪ To enable cross- functional problem solving. ▪ To build quality and reliability into the product.	▪ The company is poor at meeting quality cost and time. ▪ Unstable markets, requiring reactive product development lead-times.
Tools & Techniques	▪ To enable concurrent engineering[9]. ▪ To enable cost reduction. ▪ To build quality and reliability into the product[57]. ▪ To capture and deploy customer requirements[57].	▪ A requirement for improving product quality and reliability. ▪ A reduction is required with respect to product costs. ▪ Poor capture and dissemination of customer requirements.
Information Technology	▪ To practice concurrent engineering[58]. ▪ To enable clear product definition[58]. ▪ To build quality and reliability into the product. ▪ To centralise information to ensure data integrity[59].	▪ Within a competitive environment requiring fast product development lead-times. ▪ The company is poor at delivering a product on time. ▪ To ensure that everybody works from the same data.
Supply Chain Management	▪ To allow for early cross-functional communication with the supply chain as a means for improving product quality[60]. ▪ To practice concurrent engineering down the supply chain[60]. ▪ To select suppliers based on consistent procedures, which represent good practice.	▪ When a high proportion of design is out sourced[60]. ▪ Within a competitive environment requiring reactive product development lead-times. ▪ When suppliers are poor at delivering a product on time, to cost, and quality.
Project Management	▪ To capture and disseminate customer requirements[19]. ▪ To plan resources, time and control the delivery of a project[19]. ▪ To manage implementation[19].	▪ When a company is consistently poor at delivering projects with respect to specification, lead-time, and budget.

Table 13 Generalised Criteria for Selecting Required Components

5.1.5) Supporting Tools: Two tools were also selected from the literature to support the assessment process. These are risk assessment and forecasting.'

▪ Risk assessment is a tool that identifies and studies the likelihood that a hazard will produce adverse effects to a project[61]'. The risk approach adopted to support self-assessment has been tailored from the approach used by Lucas Engineering Systems[62]. This tool requires a facilitator and a group of senior managers to brainstorm and identify future risks, which may impact time, cost and quality, and to rate the likelihood that they will become reality.

- Forecasting is a tool used for predicting future events, so that organisations can take into consideration potential changes in market trends[63]. This tool was selected from the literature as it provides a means of viewing the future through predicting key metrics, which are related to quality, cost and time. The forecasting technique adopted is a time series technique, which uses historical patterns for predicting future trends[64].

5.2 Planning Tools

Once a current and a future state have been defined, it is necessary to plan how the company should move from one operational state to another. The system embodies a number of planning tools, where in addition to standard planning tools selected from the literature, two additional tools have been developed to support the implementation. Each will be briefly introduced.

5.2.1) A Tool for Deciding a Change Strategy: To assist in making decisions as to the speed of implementation, a decision tool for deciding a change strategy was developed from the literature by the R.E. as shown in figure 15. This was reported within Submission Six. Currently, no tool exists within the literature that guides the choice of an implementation strategy. Yet whether a radical or an incremental approach to implementation should be taken is commonly debated within the literature.

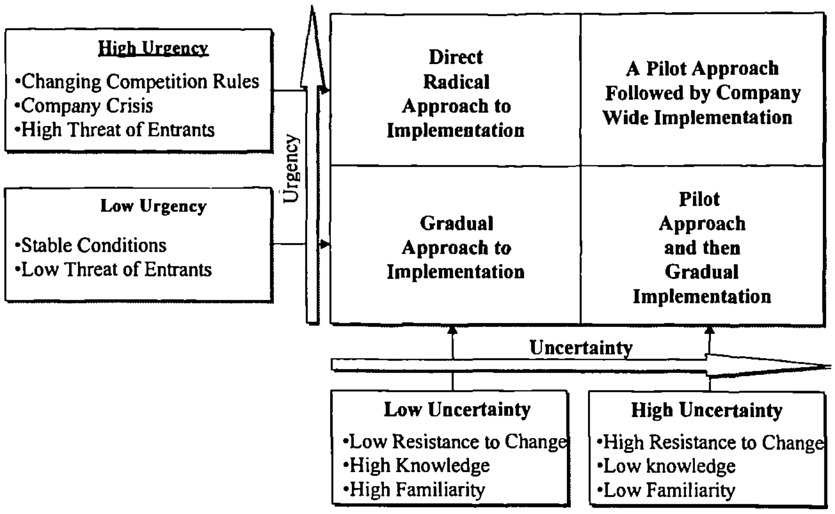

Figure 15 A Tool for Deciding a Change Strategy

As the grid illustrates there are four types of change strategies. These are:

- A *'direct radical approach'* where new tools and techniques are implemented across the whole organisation using a big bang approach.
- A *'gradual approach'* where each new tool is introduced following a step-by-step process.
- A *'pilot approach followed by company wide implementation'* where tools and techniques selected are first piloted before company wide implementation.
- Finally, a *'pilot approach followed by gradual implementation'* where all new tools are first piloted following a step-by-step process and then introduced into the organisation.

As figure 15 illustrates, to determine urgency it is necessary to identify any of the following. Risks of new competitors entering the market, opportunities to change competition rules, or to understand whether performance meets cost, quality and time targets through applying the assessment tool. Uncertainty on the other hand is determined by the degree with, which new approaches will meet scepticism or resistance from within the organisation, and whether the level of knowledge is sufficient to sustain a change program. Again figure 15 illustrates the criteria for selection.

Although not captured on the matrix, other influences may exist that determine the implementation strategy deployed. It is unlikely that a small organisation will be able to adopt a 'pilot' project independent from its main operations. Due to its size, only one project at a time may take place and therefore direct implementation of a new process within a project will be necessary. However, other practices such as new tools and techniques could be piloted independently by external resources such as Universities.

5.2.2) A Generic Planning and Guidance Tool: To assist the planning process for executing change, a tool developed by the R.E. is a generic-planning tool as shown by figure 16, and its purpose is to navigate an organisation through each maturity level. The tool defines a number of phases with activity checklists, which should be used for assisting the development of a project plan. Thus, as an example, a company, which is placed at the non-developing phase of the N.P.I. process component and wants to be a consistent performer, has to follow the activities defined within the non-developing phase maturity level 'develop systems', 'deploy' and 'assess'. The checklists can be read within appendix 3.

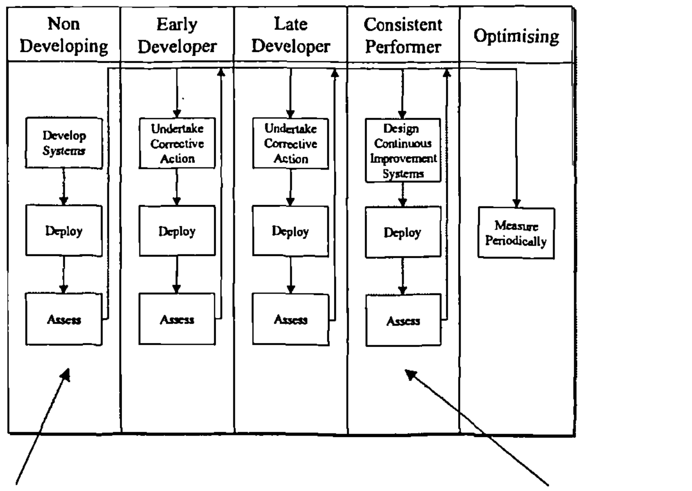

Figure 16 A Generic Planning Tool for Developing the Project Plan

5.2.3) Project Management Tools: A number of additional project management tools were selected from the literature to support the planning process. Each will be briefly reported here.

- A project structure breakdown can be used to simplify the implementation project, by breaking it down into a series of sub-projects such as defining and implementing a formal N.P.I. process, team working and I.T. systems[19]. This tool can aid the definition of a programme plan and work package time lines for each component.
- Gannt charts can be used to assist implementation by defining activities and time lines for their execution[19]. To assist in defining a project plan, the generic planning tool and the project structure breakdown should be used to identify the required activities for developing each component.
- Resource histograms are also available for establishing the resource requirements to execute each phase[19]. These should be used in conjunction with the gannt charts.

- Budget planning tools are available for predicting profiles of budget spend, and monitoring the progress of a project[19].
- Finally, a project matrix structure should be used for deploying and executing the project[53]. All functions are to be represented, and a project manager/team leader owns the change process.

5.3 Tools for Deployment

To assist in the deployment of practices, a number of tools were selected from the literature. The selection process aimed to identify tools, which supported the definition and deployment of practices such as an N.P.I. process and teamwork. Nevertheless, they are not comprehensive and additional tools can be included if required by the user.

5.3.1) Process Mapping Tools: To define a formal N.P.I. process and data architecture diagrams for a new information system, process-mapping tools have been included, such as four fields, IDEF, and input/output process-mapping tools [65] [66]. One of these should be used to define a process to different levels of detail.

5.3.2) Organisational Re-Design Methods: To support a new process, it is often necessary to re-define how people are organised for its execution. In the case of new product introduction, the team structure can dictate the overall performance of a project. Therefore, a number of tools are available for designing team structures and organisations, such as organisational charts where the 'as is' and 'to be' structure can be defined, and job design methods, which allow for specific responsibilities to be defined for project personnel[67].

5.3.3) Benchmarking: To define new processes and structures, benchmarking has been included as part of the tool kit. Benchmarking is defined as the search for industry practice that leads to superior performance[30]. Although the organisation has identified its current and future state against best practice using the self-assessment tool, benchmarking in this case requires a change project to look at other company's specific processes, structures and systems as a means of learning and understanding how they are defined.

5.3.4) Training: To assist the process of change, training is a methodology available within the tool kit for providing employees with the knowledge to embrace new working practices[68]. Training in this case should concentrate upon issues such as the need for a formal N.P.I. process, team working, and to provide knowledge and skills in specific technologies.

5.3.5) Systems Standards: Finally, to assist in institutionalising new practices, systems standards are available for documenting and embedding new practices and processes[69]. The purpose of systems standards is to document and formalise processes and practices across the organisation. These then become the foundation of all operations.

5.4 The Change Management Process

To integrate the tools so that they are used as a system, a change management process was developed (chapter 4), which has four *phases: 'where are we now? ' where do we want to go? 'plan for implementation'*, and *'deploy'*. The development of this process was undertaken in submission five.

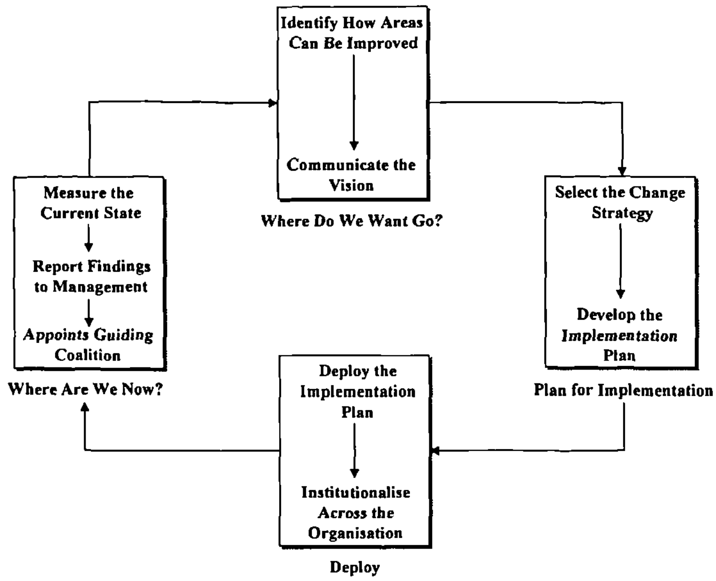

Figure 17 Implementation Process

As figure 17 illustrates, the first phase *'where are we now?'* focuses upon diagnosing and identifying that there is a need for change. The second phase *'where do we want to go?'* focuses upon strategically defining a future desired state by developing and putting in place a series of solutions for tackling the problems identified in the previous phase. The third phase *'plan for implementation'* requires the organisation to decide upon an implementation strategy, be it a radical or incremental approach, and to develop an implementation plan. Finally, the fourth phase *'deploy'* requires the implementation plan to be executed.

5.5 Integrating the Tools with the Process

Thus far the tools and the change management process have been introduced. However, how they are integrated has yet to be explained. Therefore this next section will demonstrate where and how the tools are used in the context of the change management process.

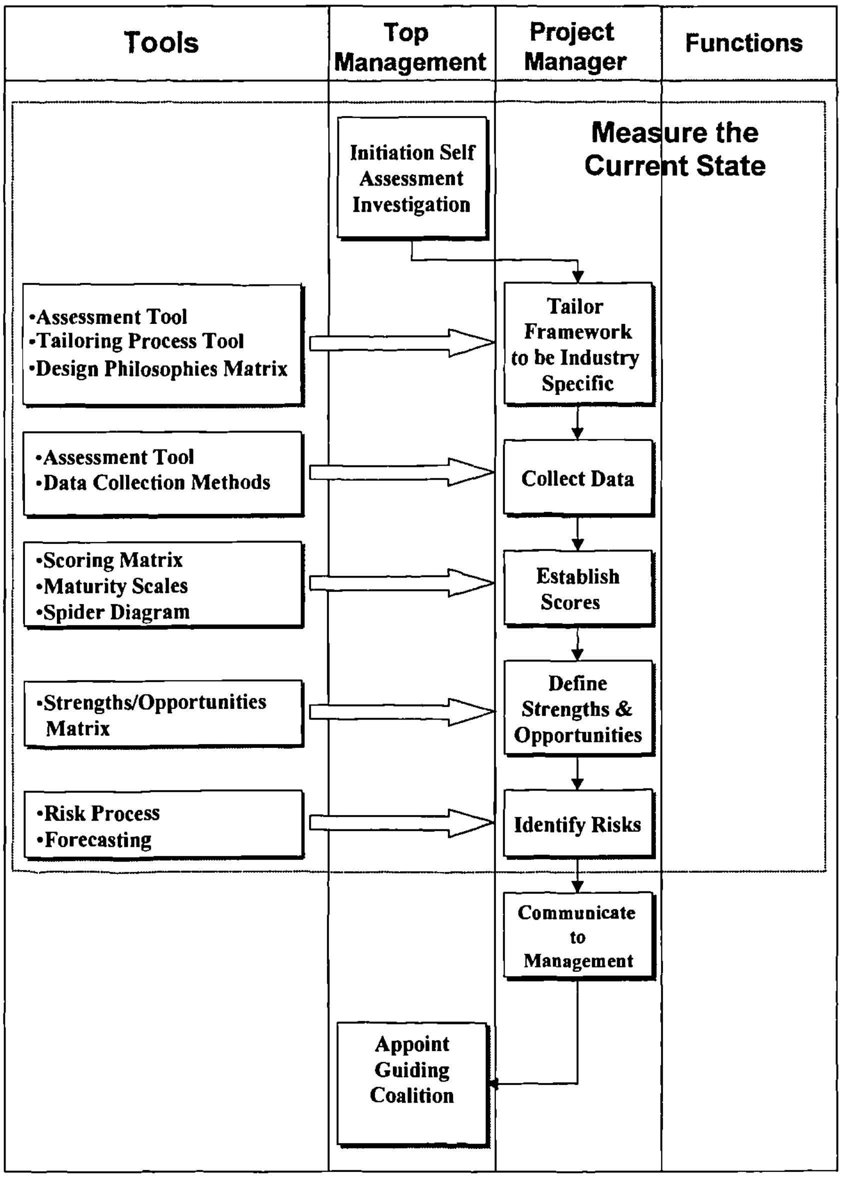

Figure 18 **Deploying Tools for Executing the First Phase of the Change Management Process**

The first phase, *'where are we now?'* is executed through applying the assessment tool. This requires the tool to be adapted by using the tailoring process tool, the design philosophies matrix, and data to be collected and scored against the criteria through applying the scoring matrix. This results in a strengths and opportunities report, a current state and a maturity level. Finally, the results are communicated to management and a guiding coalition is elected. Figure 18 demonstrates the step phases and where these tools are applied.

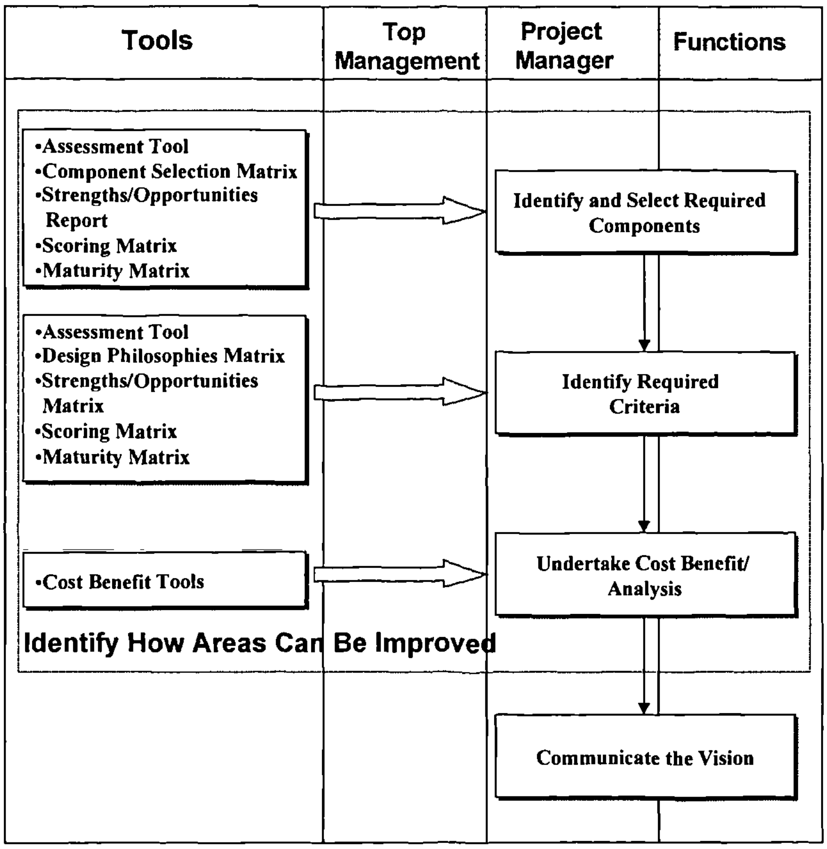

Figure 19 Deploying Tools for Executing the Second Phase of the Change Management Process

The second phase *'where do we want to go?'* is executed through again using the strengths and opportunities report defined in the previous phase to assist in identifying future improvements. Furthermore, the component selection matrix tool along with the design philosophies matrix tool, is used to select components and desirable criteria defined within the assessment tool. Finally, a future benchmarking state and maturity profile has to be defined. Figure 19 demonstrates the step phases and where these tools are applied.

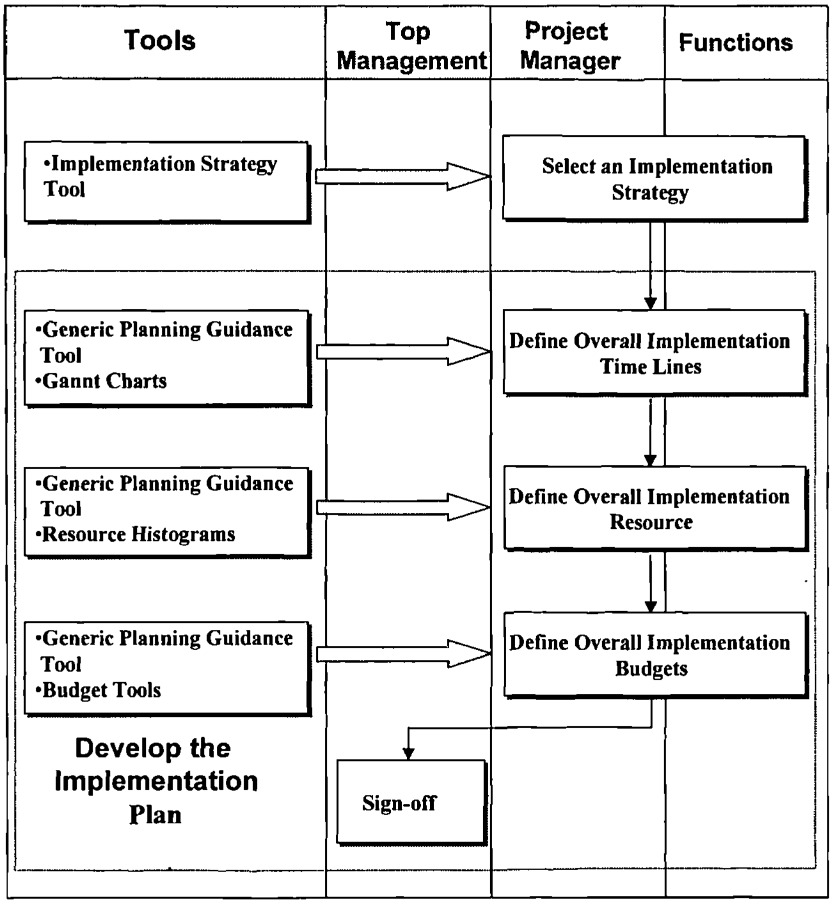

Figure 20 Deploying Tools for Executing the Third Phase of the Change Management Process

The third phase, *'plan for implementation'* is executed by deploying the strategy decision tool to decide whether to execute a radical or an incremental to implementation. Once chosen, an implementation plan is to be developed using a work structure breakdown, gannt charts, resource histograms, and budget tools for defining timing plans, resource profiles and project budgets. Figure 20 demonstrates the step phases and where these tools are applied.

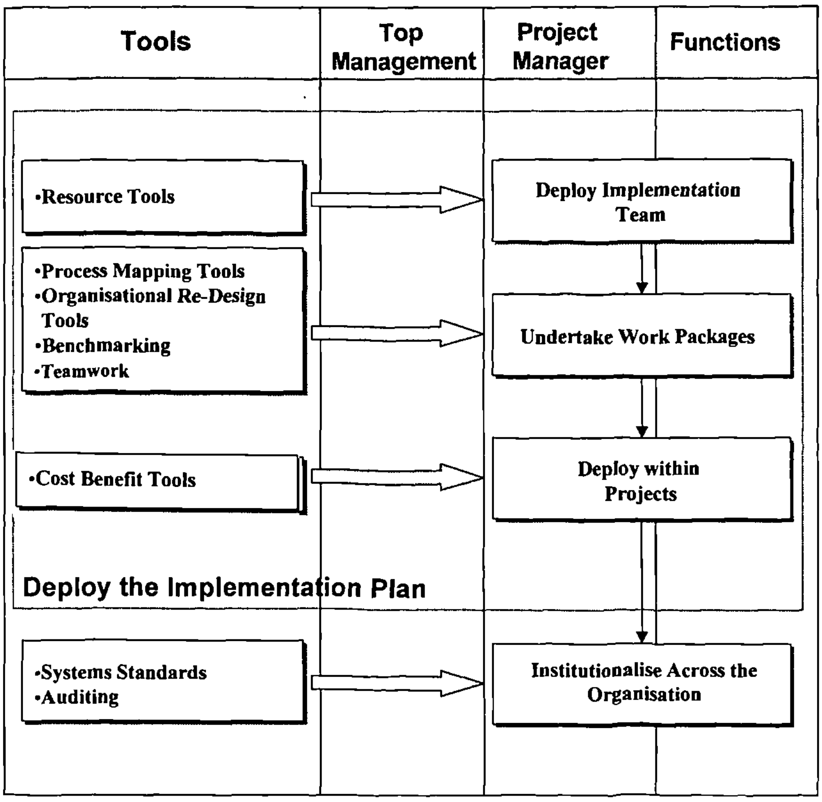

Figure 21 Deploying Tools for Executing the Fourth Phase of the Change Management Process

Finally, the fourth phase *'deploy'* is executed through applying teamwork, process mapping tools, organisational re-design tools, benchmarking, and training for developing and implementing a framework of practice within the organisation. Furthermore, to institutionalise practices, system standards are to be used. Figure 21 demonstrates the step phases and where these tools are applied.

5.6 Summary

This chapter presented a system developed by the R.E. for integrating self-assessment with a change management process. The model of CE and the change management process model developed as part of the research became central to the system. Furthermore, additional tools, developed by the R.E., were also introduced along with those selected from the literature. However, the application of the tool has yet to be reported for testing its effectiveness. Therefore, the next chapter will report the application of the tool at a UK based company.

Chapter 6 Development of an N.P.I. Process

6.0 Introduction to the Case Study

To test that the system provided a solution for UK organisations to implement CE, it was applied at London Taxis International (L.T.I.). Furthermore, the purpose of the application was to test whether the tool satisfied the following hypothesis.

'A self-assessment tool integrated with a change management process can facilitate a change program toward effective product development within a UK organisation'.

In 1998, London Taxis had delivered a new taxi, the TX1 to market. An audit undertaken by White identified that the process of development was not stable, and the company did not meet a number of project performance requirements[70]. This study led L.T.I. to recognise that they needed to be more efficient at introducing new products to market, by formalising how they undertook new product introduction. Therefore, how the tool was applied to achieve this will be highlighted.

6.1 Measure the Current State

6.1.1) Initiate Self-Assessment Investigation: The company directors initiated the change process and the Supply Chain Director was responsible for the project. Furthermore, to help manage the change process, the Research Engineer was asked to act as the facilitator. Nevertheless, for this role to be executed, it was necessary to understand the organisations current state.

6.1.2) Tailor Framework to be Industry Specific: To assist the R.E. with the facilitation process, the R.E. first had to establish the current state of the organisation. To ensure that the assessment tool was representative of L.T.I.s specific needs, it had to be tailored for L.T.I.s circumstances. Originally, this was achieved by understanding L.T.I.s key project requirements and linking them to specific design practices. However, this first approach was not formalised and inspired the development and then the re-application of the tailoring process tool for its verification as illustrated by figure 22. Data was collected from the team and the results will be summarised.

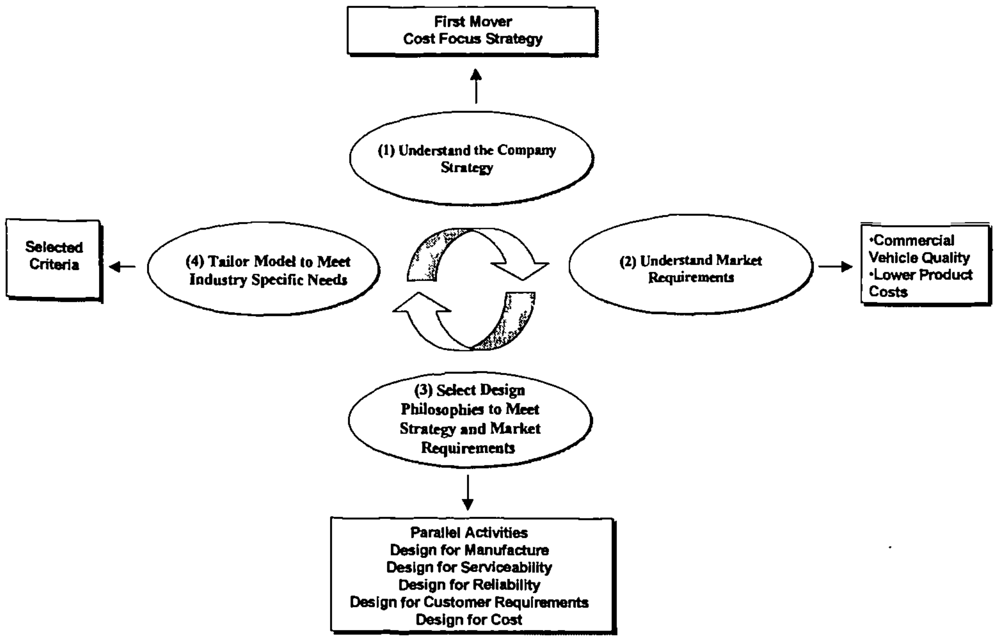

Figure 22 Applying the Tailoring Process

- **Understand the Company Strategy:** According to the Supply Chain Director, L.T.I. concentrates upon what Porter defines as a cost focus strategy where it concentrates upon the taxi market only[7]. In addition, L.T.I. wanted to be a first mover within its industry segment so that they can set industry standards.

- **Understand Market Requirements:** Market investigations revealed that within this segment taxi drivers today wanted a new purpose vehicle, which offered commercial automobile quality build standards, lower product costs, and low cost of ownership.
- **Select Design Philosophies to Meet Strategy and Market Requirements:** To meet customer requirements and its strategy, L.T.I. believed that they had to practice the following design philosophies: design for serviceability, design for reliability, design for manufacture, designs for customer requirements and design for cost to improve schedule, quality, and cost.
- **Tailor Model to Meet Industry Specific Needs:** The criteria within the self-assessment tool (appendix 1, criteria for practice and performance) were selected on the basis of whether they would meet the design philsophies chosen.

6.1.3) Collect the Data: To collect data, the criteria within the self-assessment tool provided direction on what information needed to be collected for its assessment. The R.E. used three main sources. 1) As previously stated, the audit findings presented by A White for the TX1 product development project[71]. 2) Face to face interviews with the supply chain director as a means for ascertaining answers to key questions. 3) Speaking and collecting relevant data from functional personnel whom worked within the project.

6.1.4) Establish Scores: Once the R.E. collected the data, each component within the self-assessment tool was scored by assigning a value of 1, 2 or 3 for each criterion by comparing the information found in L.T.I. against the criteria defined within the self-assessment tool by using the scoring matrix introduced in figure 13. To guide the allocation of scores, the areas to be addressed for each criterion, which are defined as part of the self-assessment tool, were referred to as a means to guide the magnitude of the score assigned. Once completed, each component was summed and normalised within a scale of 0-100. The score sheet compiled for L.T.I. can be found in appendix 4.

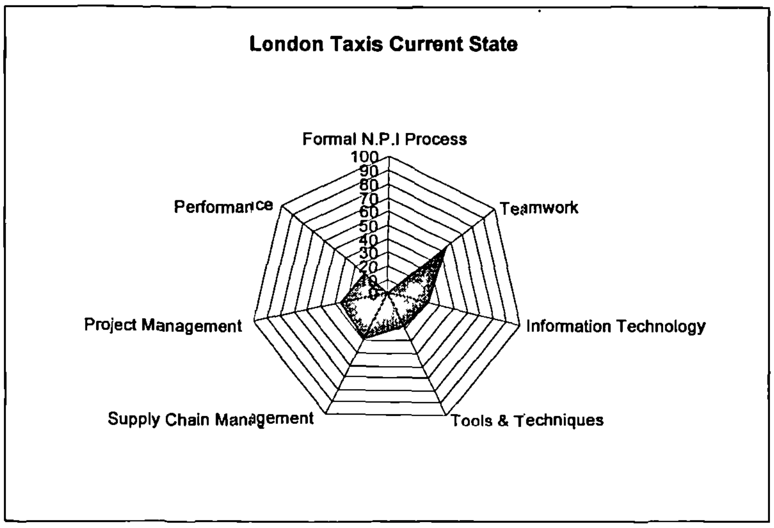

Figure 23 Spider Diagram Defining a Current State Profile for London Taxis International

	Non Developer	Early Developer	Late Developer	Consistent Performer	Optimising
Formal N.P.I Process					
Teamwork					
Information Technology					
Tool & Techniques					
Supply Chain Management					
Project Management					

Figure 24 Maturity Profile at London Taxis International

Once the total scores for each component were collated, they were presented within the spider diagram as shown by figure 23. This illustrates that L.T.I. had adopted some good practice techniques; but they were not impacting performance. Furthermore, these scores were relatively low and in terms of maturity as figure 24 illustrates, L.T.I. were still at an early developer phase and therefore further improvements could be made.

6.1.5) Define Strengths & Opportunities: Once the assessment was completed, the criteria of the self-assessment tool were categorised and translated into strengths and opportunities by the R.E. as a means to highlight potential improvement areas. Tables 14, 15, 16, 17, 18, and 19 define the strengths and opportunities for a formal N.P.I. process, teamwork, information technology, tools and techniques, supply chain management, and project management at London Taxis International.

Strengths	Opportunities
▪ *A formal N.P.I process was not found to be present.*	▪ *To define an N.P.I process that encapsulates best practice, and allows for the management of risk by defining phases of product development to different levels of detail, stage review gates, and concurrent activities. Moreover, this process should be used as a basis for planning and guiding projects.* ▪ *To implement continuous improvement activities.*

Table 14 Strengths and Opportunities for a Formal N.P.I Process at L.T.I.

Strengths	Opportunities
▪ *The deployment of a project manager who co-ordinated, and was responsible for owning and delivering the project.* ▪ *The deployment of all functional skills, this includes engineering, manufacture, purchasing, marketing, test, and after-sales within a multifunctional team.* ▪ *Project commitment between team members was found to be extremely high with respect to delivering a product on time, to cost, and quality.* ▪ *The team was structured around a product structure breakdown, which included a program team responsible for overall co-ordination and sub-system teams who were responsible for delivering each work package.* ▪ *Team members had some skills present, however these were restricted to team members undertaking functional activities rather than cross-functional activities.*	▪ *To improve the level of cross functional problem solving between team members as a means for achieving design for manufacture and assembly, serviceability, reliability, customer requirements, and cost.* ▪ *To ensure that all team members are working to a well defined N.P.I. process.* ▪ *To develop skills in designing a product to cost, manufacture, serviceability, reliability, and customer requirements.* ▪ *To encourage functional departments to work concurrently.* ▪ *To implement continuous improvement activities.*

Table 15 Strengths and Opportunities for Teamwork

Strengths	Opportunities
▪ *The deployment of CAD and solid modelling for the definition of the vehicle externals.* ▪ *The deployment and application of computational design tools during the design phases.* ▪ *The deployment of integrated project management tools for the definition of a program plan and sub-system plans, and all personnel had appropriate access to these plans.*	▪ *To use CAD for defining the whole product.* ▪ *The use of a single master model for defining the product concept, product design and manufacturing tooling.* ▪ *Simultaneous electronic definition of product systems.* ▪ *Electronic assembly of product sub-systems for analysis of shape and form.* ▪ *The use of CAD for analysing serviceability and maintainability requirements.* ▪ *Data transfer of solid models with manufacturing development tools.* ▪ *To deploy and apply CAM tools for manufacturing systems development.* ▪ *To deploy a product data management system and allow simultaneous access for all functions.* ▪ *To implement continuous improvement activities.*

Table 16 Strengths and Opportunities for Information Technology

Strengths	Opportunities
▪ *Restricted deployment of failure mode & effects analysis for understanding potential failure modes upon the vehicle doors.* ▪ *Deployment of quality functional deployment for translating the voice of the customer into technical requirements, thus enabling in part the execution of a design for customer requirements philosophy.*	▪ *The full deployment of failure mode & effects analysis as a means for practising a design for reliability philosophy.* ▪ *The deployment of design for manufacture and assembly as a means for practising a design for manufacture philosophy.* ▪ *The deployment of rapid prototyping for practising a design for manufacture philosophy.* ▪ *The deployment of value analysis tools for practising a design for cost philosophy.* ▪ *The deployment of design of experiments for practising a design for reliability philosophy.* ▪ *The deployment of process capability studies for the practice of a design for manufacture philosophy.* ▪ *To implement continuous improvement activities.*

Table 17 Strengths and Opportunities for Tools & Techniques

Strengths	Opportunities
▪ *Key first tier suppliers were identified early in the process.* ▪ *Key first tier suppliers were apart of the multifunctional team.* ▪ *Some cross-functional problem solving occurred for achieving design for manufacture occurs between engineering and first tier suppliers.* ▪ *The supply chain was structured into simple tiers.*	▪ *The use of standard supplier selection procedures to assess the ability of the supplier to deliver on time, to cost and quality.* ▪ *To deploy the process into the supply chain.* ▪ *To electronically transfer data to the supply chain.* ▪ *To implement continuous improvement activities.*

Table 18 Strengths and Opportunities for Supply Chain Management

Strengths	Opportunities
▪ *A feasibility study was undertaken for identifying the need.* ▪ *A project specification was defined encapsulating functional, reliability, aesthetics, and project requirements.* ▪ *A formal review was undertaken for authorising the project.* ▪ *An overall programme plan was developed, defining time-lines, budgets, and resource.* ▪ *Sub system plans were also developed defining time-lines, budgets, and resource.* ▪ *Regular project reviews were undertaken for monitoring and controlling the project.*	▪ *To use lessons learnt from previous projects as a means for defining the specification, and project plans.* ▪ *The use of history time lines, budgets and resource data as a means for defining project plans.* ▪ *To undertake a project risk assessment during planning to ensure that contingency measures are built into the plans.* ▪ *To use the N.P.I. process for defining requirements to be reviewed during the implementation phase.* ▪ *To undertake continuous risk assessments during the implementation phase of the project as a means for analysing and identifying changing conditions and implementing contingency plans.* ▪ *To implement continuous improvement measures.*

Table 19 Strengths and Opportunities for Project Management

6.2 Communicate to Management

The results of applying self-assessment tool were reported to the Supply Chain Director and opportunities for improvement were also reported to the L.T.I. management team responsible for undertaking the change management process. Finally, this exercise brought the Research Engineer up to speed on the current state of product development at London Taxis International.

6.3 Identify and Elect Guiding Coalition

To undertake the change-program a guiding coalition was set up which consisted of functional managers, a project manager, and the facilitator (Research Engineer). The role of the functional managers was to bring functional knowledge, the role of the project manager was to co-ordinate and manage the change program, and the role of the facilitator was to act as a catalyst to the definition and implementation of new practices.

6.4 Identify How Areas Can Be Improved

6.4.1) Identify and Select Required Components: To refer back to the performance component of the spider diagram, a number of performance measures with respect to time, cost, and quality were not been satisfied by L.T.I.. White identified a number of causes as figure 24 illustrates, each will be explained.

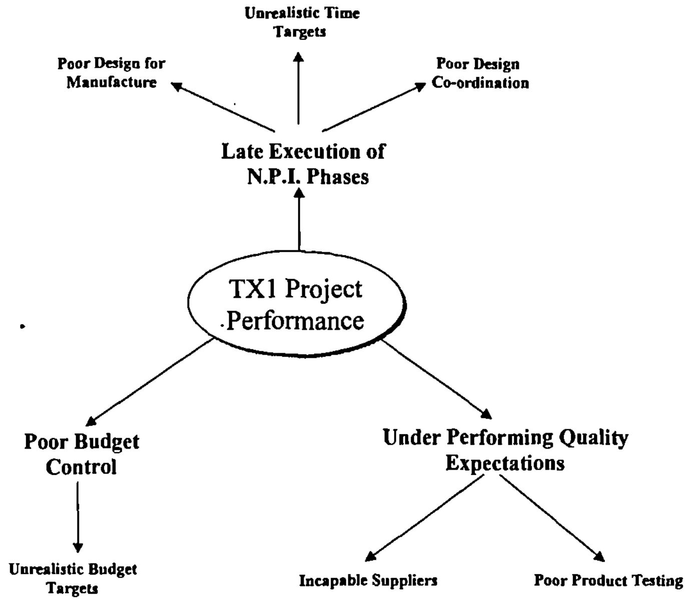

Figure 25 Factors Contributing to Poor Performance[70]

- Late execution of N.P.I. phases resulting from the following. 1) Poor design for manufacture resulting in design iterations being made later in the process. 2) Planned time targets not representing actual time taken. 3) Poor design co-ordination between product sub-systems leading to time delays.
- Poor budget control due to initial forecasted budgets not being representative of actual budgets required.
- Under performing quality expectations due to two reasons. 1) Suppliers not having capable processes, thus leading to quality problems. 2) Testing not being thorough to ensure that the product was reliable.

To tackle these issues L.T.I. realised that they had to have better project control to ensure that phases of product development were executed on time, and that budgets were controlled. Furthermore, higher levels of quality had to be attained through better product testing and designing a product for manufacture, service, cost, customer requirements and reliability. Therefore, to decide upon a future set of components, the

R.E. explained the role and purpose of each component, and their relevance in impacting project performance and product quality so that the team could decide. However, this original approach was not formalised, and an opportunity was identified which resulted in the development and re-application of the component selection matrix as defined in table 14 for selecting desired components. With reference to table 14 'conditions of use', this led to the team selecting the following components within the self-assessment tool: a formal N.P.I. process, teamwork and project management due to the following reasons.

- L.T.I. delivered the TX1 on time; however, the project missed key milestones and it did not deliver to key budget and quality targets. Therefore, a formal N.P.I. process was selected to assist in providing greater control for delivering a high capital investment vehicle on time, to cost and quality.
- Although elements of teamwork were found to be in place within the organisation. Faster product development and higher levels of product quality were required to improve delivery time and product quality. Therefore, the team-working component was selected to further enhance cross-functional problem solving between functions to achieve specified design philosophies such as design for manufacture, serviceability, reliability, customer requirements, and cost.
- Finally, although certain project management practices were found to be in place within the organisation, this component was selected for further improvements to ensure greater control of projects.

6.4.2) Identify Required Criteria: Once the components were selected it was necessary to select the desirable criteria for each component to ensure that quality, cost and time were impacted. As previously stated, L.T.I. believed that to deliver a competitive product, it had to practice design for serviceability, manufacturability, reliability, customer requirements and cost. Therefore, specific criteria were selected within each component, which would enable the practice of their chosen philosophies. Therefore figures 26 and 27 present a new set of scores representing the future target state for L.T.I.. This states that L.T.I. aspired to be consistent performers with respect to the application of a formal N.P.I. process, teamwork and project management as a means for impacting time, quality and cost.

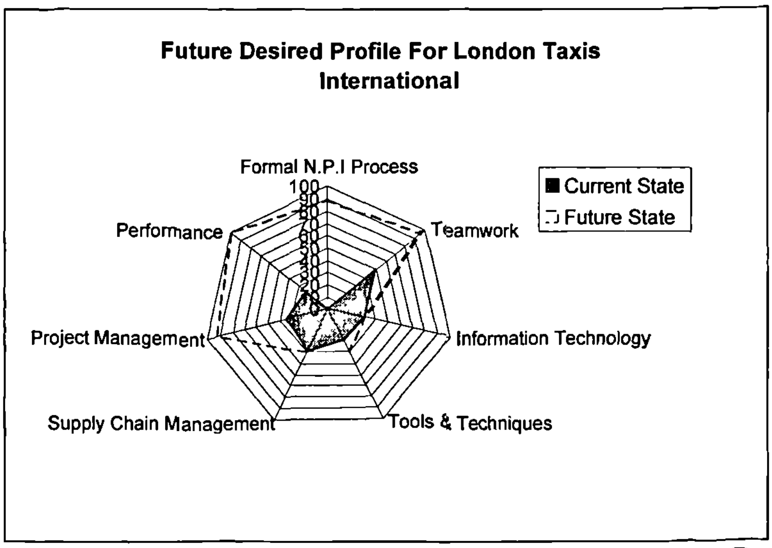

Figure 26 **Benchmarks Stating London Taxis International Desired Future State**

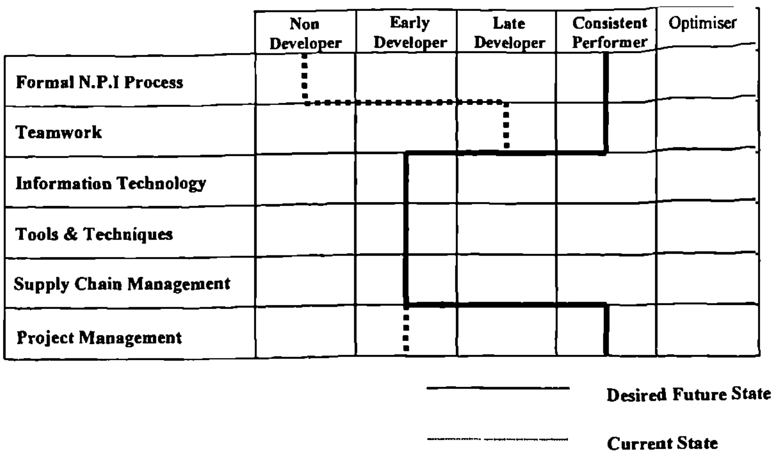

Figure 27 **Maturity Profile Stating London Taxis International Future State**

6.5 Communicate the Vision

The vision of where the organisation wanted to be was communicated to the directors by the project manager (supply chain director). However, at this stage, the project management team did not want to formally communicate the vision to the rest of the work force until its development was mature.

6.6 Select an Implementation Strategy

To plan for implementation, it was first necessary to select an implementation strategy, which would state the speed of implementation, and whether a pilot project was required. The R.E. used the rules defined by the implementation strategy tool (section 5.2.1) to facilitate the team toward a decision as illustrated by figure 28. A pilot approach followed by company wide implementation was chosen by L.T.I. where a number of small pilot style projects were identified. The reasons for this will be explained.

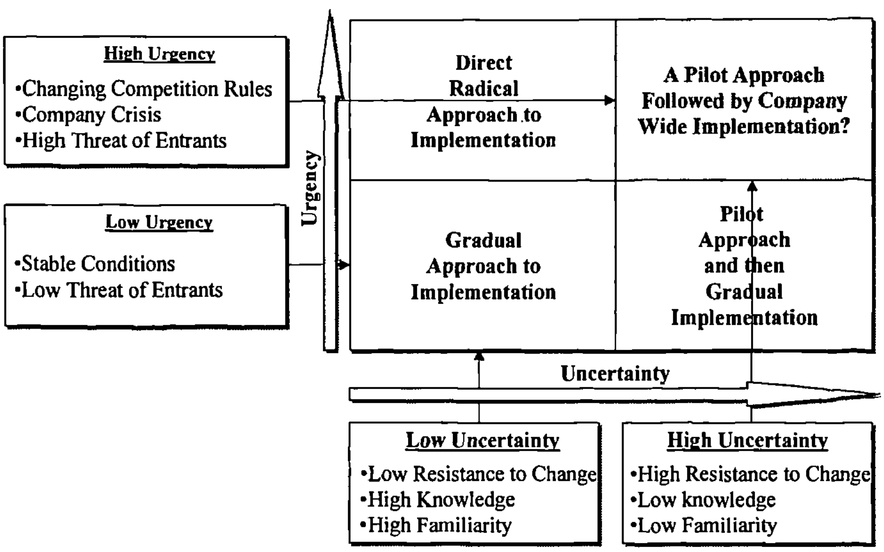

Figure 28 Deciding an Implementation Strategy at London Taxis International

Although the company was not in crisis, a high level of urgency existed with respect to implementing competitive product development practices. A number of risks were identified, which threatened the company's position. These were 1) A threat of new entrants from the commercial vehicle sectors offering a better value product with higher levels of product quality. 2) Taxi drivers themselves lobbying local governments to lift the legislation that protects the company within its market segment. In addition a high level of uncertainty existed with respect to whether the organisation would embrace the new process i.e. resistance from the workforce. A number of company directors expressed doubt as to the need of a new process and its relevance at L.T.I. Furthermore, it was felt that a low-level of knowledge existed with respect to the application of good practice tools, techniques and methodologies. Therefore, a high level of urgency and a high level of uncertainty led to a series of quick win small pilot style projects followed by company wide implementation being selected, as they felt that the pilot approach would allow familiarity and buy-in to occur.

6.7 Develop the Implementation Plan

6.7.1) Define Overall Implementation Time Lines: An informal timing plan was defined for the development of the N.P.I. process, teamwork, and project management. To define the plan, a number of activities had to be considered to develop each component. To re-emphasise, L.T.I. were found to be at the *'non developing phase'* for the formal N.P.I process, *'early developing phase'* for teamwork and *'early developing phase'* for project management. The generic-planning tool as illustrated within appendix 3 states that for non developing and early developing components, a number of key activities have to be scheduled for enabling the definition and implementation of each component, and the timing plan was defined to take into consideration these activities.

6.7.2) Define Overall Implementation Resource: To support the timing plan, implementation resource was defined for the development and implementation of the components. The guiding coalition as elected in section 6.3, were also made responsible for defining and facilitating the implementation of each component within the pilot project.

6.7.3) Define Overall Implementation Budgets: L.T.I. did not define a budget for implementing each component, as each functional department already had an allocated business improvement budget. However, on hindsight this proved to be problematic, as the training budget for each department was surpassed.

6.8 Deploy the Implementation Plan

6.8.1) Deploy the Implementation Team: To develop and implement planned practices, the implementation team, which included the project manager, the R.E., and functional managers were deployed.

6.8.2) Undertake Work Packages: Once the team was deployed, a formal N.P.I. process was developed, and improvements to teamwork and project management were undertaken.

To define the N.P.I. process, the team benchmarked (section 5.3.4) processes used by other companies to provide insight into how they were defined. A four fields based process-mapping tool (section 5.3.2) was used by the R.E. to define the process at three levels of detail; however only the first level of the process is shown in figure 29. Level one consists of six main phases, a *'business concept definition phase'*, a *'proposal definition phase'*, a *'design phase'*, a *'development and verification phase'*, a *'validation phase'*, and a *'launch phase'*. Furthermore, after each phase a business review takes place where checklists of requirements are defined. At level two, each top-level phase breaks down into a series of sub-phases. Here individual work packages were defined and specified in terms of departmental ownership. At this level concurrency was built into the process through defining specific work packages in parallel, thus providing a means to compress time to market. Finally, at the third level, the activity phase, specific work packages were defined in terms of inputs, activities to be undertaken and outputs. This can be read in greater detail within submission six.

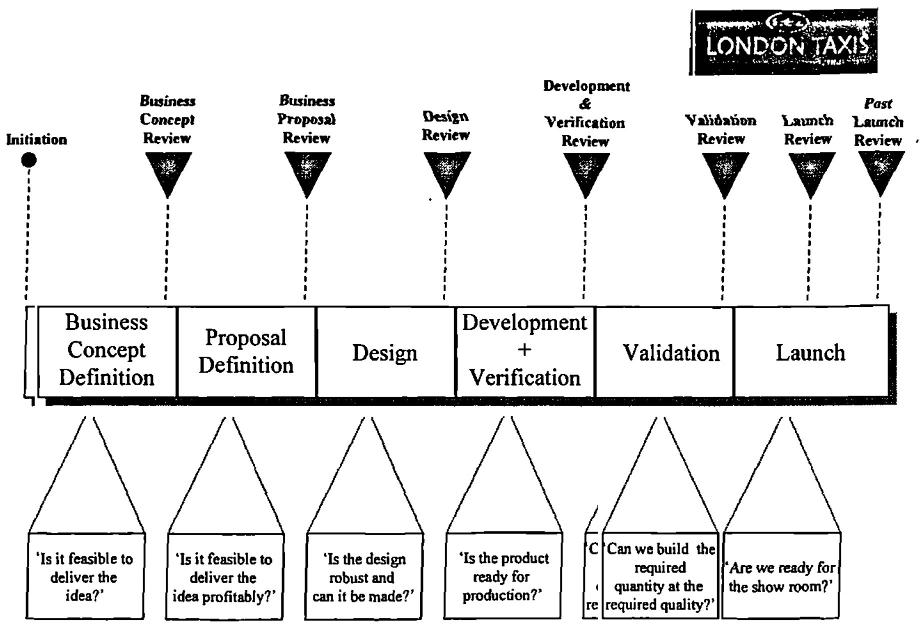

Figure 29 Systems Definition of the London Taxis International N.P.I. Process

In addition, the teamwork component was formalised to align with the process. The future state defined using the self-assessment tool was used for guiding this definition. Figure 30 presents the project structure put in place, which is essentially a matrix where the project manager is responsible for co-ordinating and managing line activities, whilst the functional managers are responsible for providing resource and technical expertise.

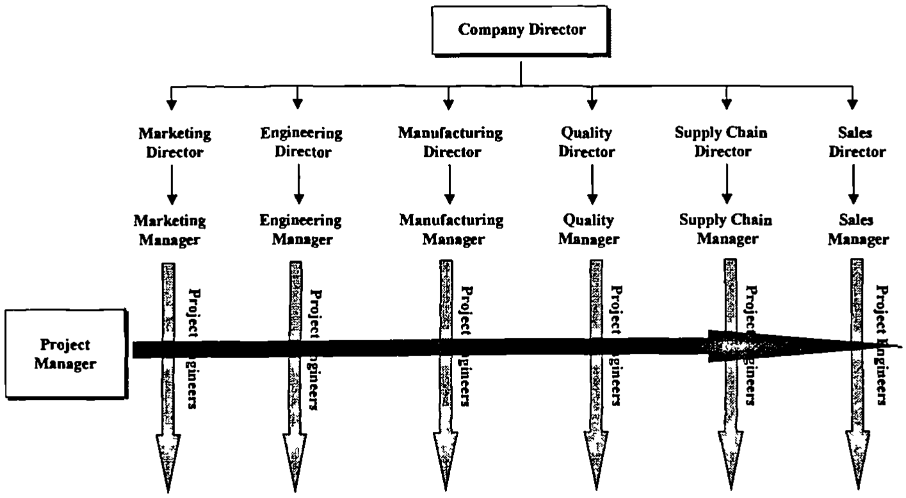

Figure 30 Formalised Project Structure at London Taxis International

Finally, the R.E. built project management activities as defined by the assessment model into the N.P.I. process. This included the following:

- A feasibility study for understanding the need for a project,
- Developing a product specification,
- Definition of resources and time-scales,
- Definition of budget targets,
- The application of a project risk assessment,
- The application of a post project learning session.

6.8.3) Deploy within Projects: To support the development of the new N.P.I. process, a general training program was provided, which aimed to give personnel at L.T.I. an insight into competitive product introduction, and its need. Moreover, the Supply Chain Director gave a series of seminars within L.T.I. communicating the N.P.I. process to senior managers and project engineers. This was undertaken to fully communicate its purpose and benefits, and to ensure that full organisational buy in was achieved. Finally, two quick win projects were set up to pilot the new process. These were of the following:

- *'Project Silver S.E.'*, a face lift project, offering further features for the customer.
- *'Project Maisy'*, a development project for redesigning vehicle electronics.

The new process is currently being deployed within these projects.

6.9 Summary

This chapter introduced the application of the self-assessment tool integrated with a change management process at L.T.I. as a means to test whether it can guide an implementation program. This led to the development of a formal N.P.I. process and corrective action being put in place for teamwork and project management. However, whether the tool is effective at leveraging CE practice has yet to be analysed. This will be undertaken within the next chapter.

Chapter 7 A Tool for Leveraging Concurrent Engineering Practice

7.0 Introduction

To test the hypothesis introduced in section 6.0 three criteria were assessed. These were: 1) Whether the system was successful at allowing change objectives to be set and achieved. 2) Whether the practices specified impacted project performance. 3) Whether the self-assessment tool integrated with a change management process impacted speed and productivity of the change program.

7.1 Performance of the System

L.T.I. understood that it had to improve product development performance, but it did not know how to get there. The following will present evidence collected from L.T.I. that show the system provided a means for improving project performance.

7.1.1) Allowing Change Objectives to be Set and Achieved: The self-assessment tool integrated with a change management process provided a route map and a set of tools in which objectives for improvement can be established and implemented within the organisation as the application at L.T.I. demonstrated. The first phase of the process 'where are we now?' allowed the current state of L.T.I. to be established through collecting information on practices utilised by the company and applying the self-assessment tool for defining a current state benchmark profile of the organisation (section 5.1.1). This was followed by the second phase 'where do we want to go?'

where the self-assessment tool was applied to identify a number of future objectives for improvement. These were the implementation of:

1. A formal N.P.I process with phases of product development, project reviews with checklists, concurrency and tier level definition of activities.
2. Teamworking improvements to enhance cross-functional problem solving between functions as a means to enable concurrency between processes, design for manufacture, design to cost, design for serviceability, design for customer requirements and design for reliability.
3. A project management process to guide the definition and implementation of an overall programme plan and work package plans using historical data, risk management tools and processes and a project de-brief as a means to control the project.

The third phase of the process 'plan for implementation' required a plan to be created for implementing the objectives. During this phase the implementation strategy decision tool as developed by the R.E. was used as illustrated within figure 15 to facilitate the decision that a pilot approach followed by company wide implementation was required. Furthermore, to assist in planning the activities necessary to achieve the improvements, the generic-planning tool was used to as illustrated by figure 16 to identify key activities. Finally, the fourth phase of the process 'deploy' required the plan to be put in place. During this phase, work was undertaken to realise the objectives defined in the second phase 'where do you want to go?' This resulted in the development and implementation of:

- A formal N.P.I process using a fields based process mapping tool (section 5.3.2) to build the following features into the process:

  1) Phases of product development combined with project reviews and checklists.
  2) Concurrent Engineering practices to enable design philosophies such as design for manufacture, and the execution of activities in parallel.
  3) The definition of the process at different levels of detail using a tier-based approach.

  Finally, once the process was defined it was piloted on the Maisie and Silver S.E. projects.

- Improved teamwork by:

  1) Appointing a project manager to lead and co-ordinate the Maisy and Silver S.E. projects.
  2) Defining concurrent activities and cross-functional working within the N.P.I. process as a means to guide communication and parallel working between team members. This practice was implemented in the Maisy and Silver S.E. projects.

  However, at this point training opportunities had not yet been identified and therefore, the objective of providing engineers with the necessary skills for effectively executing their work had not been provided.

- Project management activities by defining the need to:

  1) Develop a program plan and sub plans within the N.P.I. process and implementing this practice within projects Silver S.E. and Maisie.
  2) Undertake a project risk assessment at the planning and implementation phases of the N.P.I. process and implementing this practice within the Silver S.E. and Maisie projects.
  3) Undertake project reviews within the N.P.I. process and implementing this practice within the Silver S.E. and Maisie projects.
  4) Undertake a post project review within the N.P.I. process and executing this practice when the silver S.E. project was completed.

  However, the use of historical time data for the creation of plans was not realised. The plans developed were based upon judgement as L.T.I. did not have any past historical data in which to use.

The application at L.T.I. demonstrated that a self-assessment tool integrated with a change management process is capable of enabling improvement objectives to be identified and achieved.

7.1.2) Impact of Components upon Project Performance: The intention of applying the self-assessment tool integrated with a change management methodology is to improve an organisation's performance. To review whether the new N.P.I process and improvements made to teamwork and project management had impacted new product introduction performance; the R.E. assessed a number of performance measures as shown in table 14. These were whether the project was delivered on time, to planned milestones, to a planned budget, and finally to planned quality. Three projects were reviewed to assess the measures; projects Silver S.E. and Maisie because the N.P.I. process developed was applied within these projects, and the original TX1 project, because it was undertaken prior to the improvements. The purpose of this was to see if any differences in performance existed. Nevertheless, there are limitations with this comparison in that the TX1 was a whole vehicle project and therefore more complex than the Silver S.E. and Maisie projects, which were vehicle derivative projects.

	TX1	Silver S.E.	Maisie
Completed on Time	Yes	Yes	To schedule
Project Reviews Achieved as Planned.	No	Yes	To Schedule
Completed to Budget	No	Yes	On Target
Completed to Quality	No	Yes	-

Table 14 Measuring Performance

As table 14 illustrates the TX1 project was delivered on time, but was poor at meeting planned project reviews, budget and quality targets. This was reported to be due to a number of reasons such as poor project planning, poor project control, poor design for manufacture & assembly, and manufacturing processes not being under control.

The 'Silver S.E.' project was aimed at enhancing the product specification. This included a new paint offering, air conditioning, new bumpers, and in car entertainment. As table 14 illustrates an improvement in project performance was made which resulted in:

1) The project being delivered on time.
2) Reviews as defined by the project plan being executed as planned.
3) The budget defined being controlled and executed as planned.
4) The quality targets defined within the QA audit being met.

The Silver S.E. project illustrates that the N.P.I. process and improvements to teamwork and project management as a result of applying the self-assessment tool integrated with a change management process were impacting project performance. This could be attributed to the system embodying a model of proven CE practice, which has resulted in the following:

- Better project planning and control as a result of applying the N.P.I. process and building integrated project plans to control the project.
- Improved communication between design and manufacture as a result of increased cross-functional problem solving to ensure that the vehicle design met both design and manufacturing requirements.

Finally, project 'Maisie' at the time of the interview was still being undertaken by L.T.I.. Nevertheless some preliminary results can be used. The project had passed through a number of phases as defined by the process; these were the *'business concept definition'* the *'proposal definition'*, and currently L.T.I. were at the *'design'* phase. As table 14 illustrates the project was on schedule to be completed on time, each project review thus far was undertaken on time and the remaining reviews were forecasted to be undertaken to schedule, and the project was currently meeting its budget targets. Again this illustrates that the improvement objectives defined as a result of applying the self-assessment tool integrated with a change management process were impacting project performance. Again the reasons for this could be attributed to a proven model of CE practice being used for specifying practices, which has resulted in better project control, improved project management, and cross-functional problem solving as a result of applying the N.P.I. process, teamwork and project management.

7.1.3) Comparing Implementation Performance against Rover Group: This section will compare key performance measures relating to length of time required for defining an N.P.I. process, and the number of man hours used by Rover Group and London Taxis International (L.T.I.). The purpose of this is to review whether the self-assessment tool integrated with a change management process impacted speed and productivity of the change program. Rover was chosen, because like L.T.I., it is an original equipment manufacturer for automobiles. To ensure that a like-for-like scenario is created, this analysis will concentrate on purely the identification of the problem and the definition of the process. However, this analysis will not concentrate upon deployment, as implementation has yet to be completed at L.T.I..

Rover developed and introduced to the organisation a Project Management Policy (PMP), which aimed to integrate project management practices and N.P.I activities. Furthermore, to support the process a matrix style team structure was put in place, where a Chief Engineer was responsible for the delivery of the product. Moreover, *'areas of specialism'* supported each delivery team. This was done as a means for supporting core technical competencies.

To define and implement the PMP, it took Rover 7488 man-hours to diagnose, benchmark and define a new N.P.I. process supported by a structure as shown in table

15. However, a crude comparison against L.T.I.'s performance illustrates that through using the self-assessment system integrated with a change management process, L.T.I. only required 1776 man-hours to diagnose the problem and define the process and a structure. Based on these measures, the system was successful at leading a change program. Nevertheless, further follow up work is required at L.T.I., and it is important that the tool is further applied in other organisations to check the results for consistency.

Metrics	Rover	L.T.I
No of Man Hours	7488	1776
No of People Full Time	4.4	8

Table 15 Comparison of Measures

It is important to put this result in perspective, because there are a number of reasons for these key differences between L.T.I. and Rover. A contributing factor is that Rover Group were a company of 40,000 people, configured by two groups, Rover Cars and Land Rover, whilst L.T.I. is a single product group with approximately 800 people. Some of the differences in measures can be attributed in part to the development process at Rover being more bureaucratic due to its size, and the development process having to satisfy different vehicle groups. This in itself would add time to the process.

However, what this comparison does show is evidence that a self-assessment tool integrated with a change management process does provide an efficient alternative approach to implementing CE practices within the organisation. A possible reason for the speed of implementation at L.T.I. is that the self-assessment tool integrated with a change management process provides a focused direction that uses proven knowledge transferred from leading UK organisations.

7.2 Usability of the System

Further work is required to assess the usability of the tool, as the R.E. was familiar with its design. To achieve this, it will require a number of outside individuals to be trained in the use of the system, and they would have to use it independently for a non biased judgement to be made. Such a test would require attitudinal questionnaires to be developed, so that their views can be collated and measured.

7.3 Summary

Evidence from the preliminary test at L.T.I. suggests that the system is successful at leveraging CE practice within UK industry. First and foremost, as previously illustrated within section 7.1.1, the system provided a process in which objectives could be set and achieved. Secondly, the practices deployed as a result of the assessment tool were bringing L.T.I's projects under control as section 7.1.2 illustrates. Finally, when the implementation program undertaken was compared to Rover Groups implementation of its PMP, the process taken at L.T.I. proved to be efficient as section 7.1.3 demonstrates. Therefore, based on the results gained so far, the use of a self-assessment tool integrated with a change management process can provide a solution for leveraging CE practice, which therefore supports the hypothesis.

Chapter 8 Conclusions & Further Work

8.o Conclusions

The main theme of this engineering doctorate was to explore the research question *'how can UK industry effectively leverage concurrent engineering practices within the organisation'*. This resulted in the following objectives:

1) To develop a system, which would allow organisations to implement CE,
2) To verify that the system was effective by applying it within an organisation.

To meet these objectives a number of potential tools for implementing CE were critically reviewed. These included self-assessment, benchmarking, SWOT, auditing, kaizen, policy deployment, project management & control and work-book implementation methods. This resulted in a self-assessment tool integrated with a work book style change management process being selected as the solution. To identify potential areas for innovation, a critique of previous self-assessment tools and implementation change management workbooks was undertaken. This identified that currently both self-assessment and work-book style change management processes acted as disparate systems and that there was an opportunity to create an integrated approach which would measure current performance, assist in planning future objectives, and provide a process for managing change. Therefore, a set of requirements was defined to influence the development of the self-assessment tool integrated with a change management process. To proceed, two models were developed; a model of concurrent engineering practice representing UK industry, and a change management process model developed from the literature and verified against two case companies for implementing new tools and methodologies. The model of CE consisted of six components; a formal N.P.I. process, teamwork, tools & techniques, information technology, supply chain management and project management. The change management process consisted of four main phases; 'where are you now?', 'where do you want to go?', 'plan for implementation' and 'deploy'. The process was designed to provide a means in which to integrate the self-assessment tool. Finally, the implementation system was tested at London Taxis International.

Therefore, by satisfying the objectives, a number of innovations were achieved, which are summarised in table 16. The requirements defined for the self-assessment tool integrated with a change management process will be used as a basis for their presentation.

Specification Criteria	Innovation	Criteria Achieved
1) A self-assessment tool that defines a model of CE practice by encapsulating the accepted practices of UK industry. This will provide organisations with the means to benchmark themselves against national practice.	Yes	Partly
2) A self-assessment tool that can be tailored to an organisations specific needs.	Yes	Yes
3) A self-assessment tool which will provide an in-depth means for assessing the current state of concurrent engineering practices by reviewing both the deployment and application of methods and tools	Yes	Yes
4) Provide a company with the means to strategically plan and identify areas, which can be improved through using a result driven process.	No	Yes
5) A system which can be easily applied by knowledgeable practitioners in the field of product development.	No	No
6) A system that integrates a self-assessment tool with a change management process.	Yes	Yes
7) A tool that provides an organisation with the flexibility to choose an incremental or a radical approach to implementation.	Yes	Yes
8) A system that is well prescribed and is capable of directing a change program.	No	Yes

Table 16 A Summary of Achievements

- Specification criterion one was partly satisfied in that the system offers a benchmarking model, developed and verified from eight case study companies representing the electro/mechanical industry sectors of UK industry, but it does not represent all industry sectors. Nevertheless, research demonstrated that it enabled a UK organisation to understand its strengths and weaknesses against established UK organisations. This further extends the capability of previous tools, in that it provides a basis for an organisation to compare itself against accepted industry practices.
- Specification criterion two was satisfied, because current self-assessment tools assumed one model of practice for all organisations, which is arguably an over generalisation[43]. The self-assessment tool developed extended further the functionality of previous tools, in that the self-assessment criteria defined can be tailored to represent the required design philosophies of a specific organisation. Furthermore, this approach was verified at L.T.I..
- Specification criterion three was satisfied in that the self-assessment tool developed analysed both the deployment and application of practices. This approach was verified at London Taxis International. Previous self-assessment tools on the other hand analysed the deployment of practices, but not in relation to how they are applied for achieving design for manufacture, service, reliability etc, and whether the organisation was using them correctly. Arguably, to add full value to a project, it is imperative that tools are used correctly.
- Specification criterion four was satisfied in that the self-assessment tool enables a desired future state to be prescribed by using a results driven change philosophy, where practices are put in place to achieve specific results. This approach was verified when London Taxis International put in place practices to impact time,

cost and quality. However, this does not represent innovation as RACE and BRACE also use a result driven approach[44].

- Specification criterion five was not satisfied, because the implementation system has not yet been applied by an outside party who is knowledgeable within the field of product development. Therefore, further research is required so that this can be measured.
- Specification criterion six was satisfied in that the system developed integrated a self-assessment tool with a change management process. This extends further the functionality of current tools in that they only address the phases of *'where are we now'* and *'where do we want to go'* or in the case of implementation workbooks, a model of practice and a process of *'getting there'*. An integrated approach provides a means by which a company can measure the deployment of practice and manage its process for implementation.
- Specification criterion seven was satisfied in that a tool was developed, which allowed an implementation strategy to be prescribed. Furthermore, the tool was used to guide the selection of an implementation strategy at L.T.I.. This extends further the functionality of previous tools in that a set of rules have been defined, which allows an organisation to select an incremental or a radical approach to implementation.
- Finally, specification criterion eight was satisfied in that the application of a self-assessment tool integrated with a change management process at London Taxis International verified that it can direct a change program. This extends knowledge in that the use of such an approach for managing change has yet to be reported within literature. However, the system has only been applied within one company only, and therefore requires further application.

The use of self-assessment and change management workbooks for implementing CE is not a new phenomena. However, a review of current tools clearly demonstrated that improvements could be made. A collection of incremental innovations have been achieved to improve the implementation experience by using both self-assessment and a work book change management approach, and the above demonstrates that a system has been developed and verified, which has satisfied the initial project objectives defined. Nevertheless, there is still work to be done for its full validation. This will be discussed within further work.

8.1 Further Work

Despite the achievements of this work, a number of research areas still exist, which require further work. Each will be addressed.

8.1.1) Further Validation: Although the development of the tool has undergone a robust process of development, arguably further application is required. Firstly, although evidence has been found to support that the N.P.I. process developed and implemented at L.T.I. as a result of the self-assessment tool integrated with a change management process, additional measurements relating to cost, quality and time are required to fully understand the success of the N.P.I. process deployed. In addition, although the London Taxis International case study demonstrates that the self-assessment tool integrated with a change management process can be used for facilitating change, a further case study elsewhere is required, which emphasises both the success of the solution deployed and the usability of the system. This is necessary so that greater confidence can be gained that the process and its tools are repeatable.

8.1.2) Development of Further Modules: In addition to the above, further modules could be developed to support the self-assessment tool. Currently, the system only supports the product launch process. But, further frameworks can be developed for assessing product development strategy and culture.

8.1.3) Automating the Process: The process developed is a paper-based approach. To assist the system, development of computer software may enhance implementation. Multimedia aids can enhance training, and provide support during the execution of activities.

8.1.4) Further Research To Investigate Diversification of Application: The current research primarily focused upon using self-assessment integrated with a change management methodology for assessing and deploying new product introduction practices. However, it is the belief of the R.E. that this approach can be extended to the implementation of other practices such as the procurement process or the administration of intellectual property rights. Therefore, further research could be conducted to investigate this issue.

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Appendix 1

Criterion Parts & Requirements for Consistency

Introduction

The following are the 'criteria parts for practice and performance' and 'requirements for consistency'. This defines in greater detail the components first introduced within section 5.1.1. The criterion parts are to be read in conjunction with 'requirements for consistency', which follows the criterion parts for practice for assessing the organisation.

Criterion Parts for Practice

Formal N.P.I. Process:

Section A

1	*A Standard Documented New Product Introduction Process.*
2	*Clear Definition of Concept Design Activities.*
3	*Clear Definition of Product Design and Development Activities.*
4	*Clear Definition of Manufacturing Design Activities.*
5	*Clear Definition of Test Development Activities.*
6	*N.P.I Process Is Defined To Different Levels Of Detail.*
7	*Clear Definition of Milestones with Checklists.*
Parallel Activities Only	
8	*Concurrency Is Built Into The Process.*
9	*The Formal N.P.I. Process Is Used For Defining Project Plans.*
Tier Suppliers Only	
10	*Product Design And Development Activities Are Clearly Integrated with the Customer (See standards such as QS9000, which aim to standardise a process down Ford's, Chrysler's and GM's supply chain).*

- **Section B**

11	*Continuous Identification Of Appropriate Improvements To Enhance Product Development Activities.*

Table 1 Criterion for Formal N.P.I. Process

Teamwork

- **Project Manager**

12	*Deployment Of A Project Manager Who Is Responsible For Delivering The Project.*
13	*The Project Manager Is Responsible For Executing All Project Management Related Responsibilities.*

- **Design Engineers**

14	*Deployment of Design Engineers Within The Multifunctional Team.*
15	*Design Engineers Have The Appropriate Skills For Effectively Undertaking Their Work.*
16	*Design Engineers Undertake All Design Related Activities As Specified In The Formal N.P.I Process.*

17	*Design Engineers Focus Upon identifying New and Innovative Designs for Improving Product Performance, Quality & Reliability*

Parallel Activities Only

18	*Design Engineers Execute Work Packages Concurrently With Down Stream Work Packages.*

Design for Customer Requirements Only

19	*Cross Functional Problem Solves Design Issues With Marketing At The Early Phases Of The Process.*
20	*Cross Functional Problem Solves Engineering Requirements With Purchasing At The Early Phases Of The Process.*

Design for Manufacture Only

21	*Cross Functional Problem Solves Design Issues with Manufacturing at the Early Phases Of The Process.*

Design for Reliability Only

22	*Cross Functional Problem Solves Design Issues with Test at the Early Phases of the Process.*

Design for Serviceability

23	*Cross Functional Problem Solves Design Issue with Aftersales at the Early Phases of the Process*

Design for Manufacture Only

24	*Cross Functional Problem Solves Design Issues with Purchasing on Issues of Manufacturability at the Early Phases Of Product Development.*

Design for Reliability

25	*Cross Functional Problem Solves Design Issues with Purchasing on Issues of Test at the Early Phases of the Process.*

26	*Design Engineers are Committed to the Project.*

- **Manufacturing Engineers**

27	*Deployment of Manufacturing Engineers within the Multifunctional Team.*
28	*Manufacturing Engineers Have the Appropriate Skills for Effectively Undertaking their Required Work.*
29	*Manufacturing Engineers Undertake Manufacturing Related Activities as Specified in the Formal N.P.I Process.*

Parallel Activities

30	*Manufacturing Engineers execute work packages concurrently with up-stream work packages*

Design for Manufacture Only

31	*Cross Functional Problem Solves Issues of Manufacturing Process Capability With Design Engineering At The Early Phases of the Process.*

Design for Customer Requirements Only

32	*Cross Functional Problem Solves Issues of Manufacturing Process Capability with Marketing During Concept Development.*

33	*Manufacturing Engineers are Committed to the Project.*

- **Purchasing Engineers**

34	*Deployment of Purchasing Team Members Within The Multifunctional Team.*
35	*Purchasing Engineers Have The Appropriate Skills For Effectively Undertaking Their Work.*
36	*Purchasing Engineers Undertake All Purchasing Related Activities As Specified In The Formal N.P.I Process.*

Parallel Activities Only

37	*Purchasing Engineers Execute Work Packages Concurrently With Up-Stream And Down-Stream Work Packages.*

Design for Customer Requirements

38	*Purchasing Engineers Communicate Design Requirements to Suppliers Early In The Process*

Design for Manufacture Only

39	*Cross Functional Problem Solves Manufacturing Issues with Design at the Early Phases of the Process With Regards To Supplier Systems.*

Design for Reliability Only

40	*Cross Functional Problem Solves Test Requirements with Design at the Early Phases of the Process With Regards To Supplier Systems.*

41	*Purchasing Engineers Are Committed to the Project.*

- **Marketing Personnel**

42	*Deployment of Marketing Team Members Within The Team.*
43	*Marketing Team Members Have The Appropriate Skills For Undertaking their Required Work.*
44	*Marketing Undertake All Marketing Related Activities As Specified By The Formal N.P.I Process.*

Design for Customer Requirements Only

45	*Cross Functional Problem Solves Issues of Concept Development With Design At The Early Phases Of The Process.*

Design for Manufacture Only

46	*Cross Functional Problem Solves Issues of Concept Development With Manufacturing At The Early Phases Of The Proces.*

47	*Purchasing Engineers Are Committed To The Project.*

- **Test**

48	*Deployment Of Test Engineers Within The Team (See Sub 45, Section 4.2.5)*
49	*Test Team Members Have The Appropriate Skills for Undertaking The Required Work.*
50	*Test Undertake All test Related Activities As Specified In The Process.*

Parallel Activities Only

51	*Test Execute Work Packages Concurrently With Up-Stream And Down Stream Activities Concurrently.*

Design for Reliability Only

52	*Cross Functional Problem Solved Issues of Testability With Design Engineering During The Early Phases Of Product Development.*

53	*Test Engineers Are Committed To The Project.*

- **After Sales Engineers**

54	*Deployment of After Sales Engineers Within The Multifunctional Team.*
55	*After Sales Team Members Have The Appropriate Skills For Undertaking The Required Work.*
56	*After Sales Undertake All After Sales Related Activities As Defined In The Formal N.P.I Process.*

Parallel Activities Only

57	*After Sales Execute Work Packages Concurrently With Up-Stream And Down-Stream Work Packages.*

Design for Serviceability Only

58	*Cross Functional Problem Solves Issues Of Serviceability With Design During The Concept And Design Phases.*

59	*After Sales Engineers Are Committed To The Project.*

- **Team Structure for Complex Products Only**

60	*Deployment Of A Matrix Based Team Structure.*
61	*Deployment Of A System Team.*

62	*Deployment Of A Sub Systems Teams Organised Around A Product Structure Breakdown.*
63	*Deployment Of An Extended Team.*
64	*Devolved Accountabilities.*
65	*Devolved Decision-Making.*

- **Team Structure for Simple Products Only**

66	*Deployment Of A Matrix Based Team Structure.*
67	*Deployment Of A System Team.*
68	*Deployment Of An Extended Team To Deliver A Product Structure Breakdown.*
69	*Devolved Accountabilities.*
70	*Devolved Decision-Making.*

Section B

71	*Team Members Are Involved In The Continuous Identification Of Improvements To Enhance Teamwork Within Product Development.*

Table 2 Criterion for Teamwork

Information Technology

- **Computer Aided Design**

72	*Deployment of Computer Aided Design Tools.*
73	*Application of CAD Systems At the Concept, Design And Manufacturing Stages.*
74	*Simultaneous Electronic Definition Of Product Sub-Systems.*

Design For Manufacture Only

75	*Electronic Assembly Of Product Systems for Analysis Of Shape And Form.*

Design for Serviceability Only

76	*Electronic Analysis Of Product Systems For Ease Of Maintenance.*

Design for Manufacture Only

77	*Data Transfer Of Design Models With Manufacturing CAM Tools at the Design Stage.*

- **Computer Aided Manufacture**

78	*Deployment Of CAM Tools For Manufacturing Systems Development.*
79	*Application OF CAM Tools For Production Design.*

- **Computational Design Tools**

80	*Deployment Of Computational Design Tools.*
81	*Application OF Computational Design Tools At the Concept And Design Stages.*

- **Product Data Management (Complex Products Only)**

82	*Deployment Of A Product Data Management System.*
83	*Upstream And Downstream Functions Have Access To The Appropriate Product Related Data Throughout The N.P.I Process.*

- **Integrated Project Management Tools for Complex Products Only**

84	*Deployment Of An Integrated Project Management System.*
85	*Electronic Definition Of The Programme Plan.*
86	*Electronic Definition Of Project Plans.*
87	*All Teams Have Appropriate Access To Project Plans.*

Section B

88	*Continuous Identification of Appropriate Improvements To Enhance Product Development.*

Table 3 Criterion for Information Technology

Tools & Techniques

- **Design for Manufacturability and Assembly (Design for Manufacture)**

89	*Deployment Of Design For Manufacturability and Assembly Tools.*
90	*Design For Assembly Is Applied At The Concept and Design Phases.*

- **Value Analysis (Design for Cost)**

91	*Deployment Of Value Analysis.*
92	*Value Analysis Is Applied at the Concept and Design Phases.*

- **Failure Mode & Effects Analysis (Design for Reliability)**

93	*Deployment Of Failure Mode & Effects Analysis.*
94	*Failure Mode & Effects Analysis Is Applied AT The Concept And Design Phases.*

- **Design Of Experiments (Design for Reliability)**

95	*Deployment Of Design Of Experiments.*
96	*Design Of Experiments Is Applied At The Concept And Design Phases.*

- **Modular Design (Design for Serviceability)**

97	*A Modular Design Methodology Is Targeted To Give Ease Of Product Serviceability.*

- **Quality Function Deployment (Design for Customer Requirements)**

98	*Deployment Of Quality Function Deployment.*
99	*QFD Is Applied At The Front End Of The Process.*

- **Rapid Prototyping (Design for Manufacture and Reliability)**

100	*Deployment Of Rapid Prototyping .*
101	*Rapid Prototyping Is Deployed At the Front End Of The Process.*

- **Process Capability Studies (Design for Manufacture)**

102	*Deployment Of Process Capability Studies.*
103	*Capability Studies Are Undertaken At The Early Phases Of The Process.*

Section B

104	*Continuous Identification Of Improvements To Enhance Product Development.*

Table 4 Criterion for Tools & Techniques

Supply Chain Management

- **Supplier Selection**

105	*Suppliers Are Selected Based Using Selection Procedures.*

- **Supplier Integration**

106	*Suppliers Are Integrated Into The Formal N.P.I Process.*
107	*Key Suppliers Are Apart Of The Multifunctional Team.*

Design for Manufacture Only

108	*Suppliers Carry Out Cross-Functional Problem Solving With Purchasing On Issues Of Manufacturability At The Early Phases Of The Process.*
109	*Electronic Data Is Exchanged Throughout The Supply Chain.*

Design for Reliability Only

110	*Suppliers Carry Out Cross Functional Problem Solving With Purchasing On Issues of Test Requirements At The Early Phases OF The Process*

Design for Customer Requirements

111	*Suppliers Cross Functional Problem Solves With Purchasing Engineering Requirements.*

- **Simple Tiered Structures**

112	*The Supply Chain That Supports The Project Is Structured Into Simple Tiers.*

Section B

113	*Continuous Identification Of Improvements To Enhance Product Development.*

Table 5 Criterion for Supply Chain Management

Project Management

- **Project Initiation:**

114	*A Feasibility Study To Identify The Need For The Product.*
115	*A Project Specification Defining Both Product And Project Requirements.*
116	*A Formal Project Review For Authorising The Project.*

- **Project Planning**

Multi Development Environment Only

117	*An Overall Development Plan To Ensure The Correct Prioritisation Of Projects.*

Complex Products Only

118	*The Development Of An Overall Programme Plan.*
119	*The Development Of Sub System Plans.*
120	*The Development Of Work Package Plans.*

Parallel Activities

121	*Concurrency is built into the project plans as defined by the formal N.P.I process*

Non Complex Products Only

122	*The Development Of Project Plans.*
123	*The Development Of Work Package Plans.*

Parallel Activities

124	*Concurrency Is Built Into Project Plans As Defined By The Formal N.P.I Process.*

125	*The Use Of Historical Time Data for defining plans.*
126	*Project Risk Assessments Are Undertaken.*

- **Project Implementation**

127	*Teams Conduct Regular Program Reviews For Monitoring Progress.*
128	*Continuous Programme Risk Assessments Are Undertaken To Identify New Hazards And Implement Contingency Plans.*

- **Project Closedown**

129	*Deployment Of A Project Debrief.*

Section B

130	*Continuous Identification of Improvements to Maximise the Contribution of Project Management to Product Development.*

Table 6 Criterion for Project Management

Criterion Parts for Performance

Performance:

- **Time**

131	*The Project Is Delivered On Time.*
132	*Phases of Product Development are Executed on Time.*

- **Cost**

Product Cost

133	*The Product Is Delivered To Cost As Defined* In The Specification.

Budget Cost

134	*The Actual Project Cash Flow Meets Predicted Project Cash Flow.*
135	*The Overall Project Is Delivered To Budget.*

- **Quality**

Process Quality

136	*Engineering Design Changes Occur At The Front End of Product Development.*

Product Quality

137	*The Product Meets Reliability And Maintainability Targets As Defined In The Specification.*
138	*The Product Meets Functional Requirements As Defined In The Specification.*
139	*Patents Have Been Filed To Protect New Innovative Designs*
140	*Design Rights Have Been Filed For New Aesthetic Profiles & Styles*

Table 7 Criterion for Performance

Part 2 Requirements for Consistency

Formal N.P.I Process[1]

Reference No	Assessment Methods	Requirements for Consistency
Reference 1	▪ Formal N.P.I Process	▪ Phases of Product Development ▪ Stage Gate Methodology
Reference 2	▪ Formal N.P.I Process ▪ Interview Project Manager Quality Manager	Definition of concept design activities such as: ▪ Capturing customer requirements ▪ Product planning ▪ Definition of the product specification ▪ Project Plans ▪ Resources ▪ Budgets ▪ Initial concept definition ▪ Definition of initial bill of materials ▪ Definition of initial prototype ▪ Demonstration of new technologies ▪ Identification of critical suppliers
Reference 3	▪ Formal N.P.I Process ▪ Interview Project Manager Quality Manager	Definition product design and development activities such as: ▪ Detailed product design ▪ Development of the quality plan ▪ Prototype Parts ▪ Assemble Prototype for function form and fit ▪ Procurement of parts for detailed prototype build ▪ Development of maintenance manuals ▪ Design reviews
Reference 4	▪ Formal N.P.I Process ▪ Interview Project Manager Quality Manager	Definition of manufacturing activities such as: ▪ Design of manufacturing processes ▪ Procurement of new equipment and machinery. ▪ Process capability studies for new parts. ▪ Validation of production line ▪ Full production ramp up
Reference 5	▪ Formal N.P.I Process ▪ Interview Project Manager Quality Manager	Definition of test activities such as: ▪ Definition of test plan ▪ Design of tests ▪ Execution of tests
Reference 6	▪ Formal N.P.I Process ▪ Interview Project Manager Quality Manager	Definition of the process at different levels of detail by identifying: ▪ Business process level ▪ Sub process level ▪ Activity level
Reference 7	▪ Formal N.P.I Process ▪ Interview Project Manager Quality Manager	Gate reviews defined at the beginning and end of each phase stating the following requirements[1 2 3]: ▪ Phase requirements ▪ Time performance measures ▪ Cost performance measures ▪ Budget performance measures ▪ Quality performance measures
Reference 8	▪ Formal N.P.I Process ▪ Project Plans ▪ Interview Project Manager	Evidence of concurrent engineering practices such as: ▪ Phases of product development defined in parallel ▪ Evidence of design for manufacture practices ▪ Evidence of design for serviceability activities ▪ Evidence of design for reliability activities

		▪ Evidence of design for customer requirement activities ▪ Evidence of design for cost activities
Reference 9	▪ Formal N.P.I Process ▪ Project Plans ▪ Interview Project Manager	Evidence of the N.P.I process being used for project planning by identifying the following: ▪ Phases of N.P.I defined as time lines ▪ N.P.I reviews defined into project plans ▪ Parallel activities within the project plan
Reference 10	▪ Customer Formal N.P.I Process	Evidence of the N.P.I process being integrated with the customers process by identifying the following ▪ Integrated phases of N.P.I ▪ Integrated reviews
Reference 11	▪ Interview Project Manager Quality Manager	Appropriate improvements being suggested and identified through the following: ▪ Suggestion schemes ▪ Financial justification ▪ Evidence of implemented improvements

Teamwork

Reference No	Assessment Methods	Requirements for Consistency
Reference 12	▪ Interview Program Manager	Project manager with the following skills: ▪ Leadership skills ▪ Technical knowledge ▪ Financial skills ▪ Resourcing skills ▪ People skills
Reference 13	▪ Interview Program Manager	Responsibilities such as: ▪ Developing project time lines ▪ Developing project resources ▪ Developing budgets ▪ Co-ordinating ▪ Communicating the specification ▪ Overseeing implementation
Reference 14	Interview ▪ Project Manager	Design engineers such as: ▪ Industrial designers ▪ Stress engineers ▪ Design engineers ▪ Weights engineers ▪ Dynamics engineers ▪ Electrical engineers
Reference 15	Interview ▪ Project Manager	Knowledge and skills in areas such as: ▪ Technologies ▪ Creativity ▪ Problem solving ▪ Application of quality & reliability tools ▪ Application of CAD and Computational Design Tools ▪ Experience
Reference 16	Interview ▪ Project Manager	Activities undertaken by design as specified in the process, such as: ▪ Product planning ▪ Concept development ▪ Defining the bill of materials ▪ Detailed design ▪

Reference 17	Interview • Design	Evidence required of Design Engineers • Understand the current state of the art. • Identifying strengths and weaknesses of current design solutions. • Brain storming and identifying alternative designs. • Creating new patentable solutions for problems.
Reference 18	Interview ▪ Project Manager	Design undertaking work packages in parallel with ▪ Manufacturing work packages ▪ After-sales work packages ▪ Purchasing work packages ▪ Test work packages
Reference 19	Interview ▪ Design ▪ Marketing	Design engineers cross functional communicating with marketing the limitations of new concepts by pointing out issues such as ▪ Feasibility of the concept meeting customer requirements ▪ Feasibility of whether the concept can be designed ▪ Feasibility of the concept meeting cost targets
Reference 20	Interview ▪ Design ▪ Purchasing	Design cross-functional communicating with purchasing engineering requirements such as: ▪ Required Functionality ▪ RAMS ▪ LCC ▪ Serviceability ▪ Test
Reference 21	Interview ▪ Design ▪ Manufacture	Design engineers cross-functional communicate with manufacture at the early phases of the process on issues of the following[2]: ▪ Requirements ▪ Can it be made? ▪ Can the design be made to cost? ▪ What parts can be reduced with current processes? ▪ Can parts be reduced with new processes? ▪ Are processes in control? ▪ What are the process parameters?
Reference 22	Interview ▪ Design ▪ Test	Design engineers cross-functional communicate with test on issues such as[3]: ▪ What is to be tested? ▪ The experimental requirements ▪ What are the limitations of design respect to testing?
Reference 23	Interview • Design • Aftersales	Design engineers cross-functional problem solving with aftersales on issues such as: • Service requirements • Can it be designed? • Maintenance turnaround time targets.
Reference 24	Interview ▪ Design ▪ Purchasing	Design engineers cross-functional problem solving manufacturability issues with purchasing on issues such as[2]: ▪ Requirements ▪ Can the supplier make it? ▪ Can it be made to cost? ▪ Are their processes in control?
Reference 25	▪ Design ▪ Purchasing	Design engineers cross-functional communicate with purchasing on issues such as[3]: ▪ What the supplier needs to test? ▪ The experimental requirements ▪ What are the limitations of design respect to testing?
Reference 26	▪ Interview Project Manager Design engineers	Commitment by showing dedication to the following: ▪ Budgets ▪ Time lines

		▪ Milestone Delivery ▪ Specification
Reference 27	▪ Interview Project Manager	Manufacturing engineers such as: ▪ Manufacturing systems engineers ▪ Tooling engineers ▪ Process engineers
Reference 28	▪ Interview Project Manager Manufacturing Engineers	Knowledge and skills in areas such as: ▪ Technologies ▪ Creativity ▪ Process design ▪ Tooling design ▪ Application of CNC and CAM ▪ Experience
Reference 29	▪ Interview Project Manager Manufacturing Engineers	Activities undertaken by manufacturing as defined by the process, such as: ▪ Design of manufacturing processes ▪ Development of tooling ▪ Validation of production methods
Reference 30	Interview ▪ Project Manager	Manufacturing undertaking work packages in parallel with: ▪ Design work packages ▪ Purchasing work packages ▪ After-sales work packages ▪ Test work packages
Reference 31	Interview ▪ Manufacturing ▪ Design	Cross functional problem solves issues of manufacturing process capability with design engineering at the early phases of the process on issues such as[3]: ▪ What is to be made? ▪ Can it be made ▪ Whether processes are in control ▪ Reducing the number of product parts ▪ Meeting product target costs ▪ Trading off solutions to balance cost, quality, and time
Reference 32	Interview ▪ Manufacturing ▪ Marketing	Cross functional problem solves issues of manufacturing process capability with marketing during concept development on issues such as: ▪ Whether they have capability to meet requirements ▪ What new process investments will be required ▪ Trading off solutions to balance cost, quality and time
Reference 33	Interview ▪ Project Manager	Commitment by showing dedication to the following: ▪ Achieving product costs ▪ Quality ▪ Time-scales ▪ Specification ▪ Project Plan
Reference 34	Interview ▪ Project Manager	Deployment of purchasing team members within the multifunctional team such as: ▪ Product systems, sub-systems and component purchasers ▪ Purchasers for manufacturing technology
Reference 35	Interview ▪ Purchasing Manager ▪ Project Manager	Knowledge and skills in areas such as: ▪ Auditing skills ▪ Engineering skills ▪ Cost analysis skills ▪ Supply chain design skills
Reference 36	Interview ▪ Purchasing Manager ▪ Project Manager	Purchasing undertake all purchasing related activities sas specified in the formal N.P.I process. Activities such as: ▪ Selecting suppliers

		▪ Developing make v.s. buy policies ▪ Ensuring that suppliers have capable processes ▪ Scheduling supplier deliveries
Reference 37	Interview ▪ Purchasing Manager ▪ Project Manager	Purchasing undertake work packages in parallel with: ▪ Marketing work packages ▪ Design work packages ▪ After-sales work packages ▪ Test work packages
Reference 38	Interview • Purchasing • Project Manager	Cross functional problem solves requirements with the supplier at the early phases of the process to communicate • Requirements • Discuss the potential solutions? • Can they make it? • Can they test it? • Costs
Reference 39	Interview ▪ Purchasing Manager ▪ Project Manager	Cross functional problem solves supplier manufacturability issues with design at the early phases of the process on issues such as[3]: ▪ What is to be made ▪ Can it be made ▪ Meeting product target costs ▪ Whether process are capable
Reference 40	Interview • Purchasing Manager • Project Manager	Cross functional problem solves supplier test issues with design at the early phases of of the process on issues such as: • Test requirements • Whether it can be tested • Design of experiments
Reference 41	Interview ▪ Project Manager	Commitment by showing dedication to the following: ▪ Achieving product costs ▪ Quality ▪ Time-scales ▪ Specification
Reference 42	Interview ▪ Project Manager	Deployment of marketing team members
Reference 43	Interview ▪ Marketing Manager ▪ Project Manager	Knowledge and skills in areas such as: ▪ Customer requirements ▪ Data collection and analysis ▪ Understanding customer needs ▪ Documenting needs into technical requirements ▪ Communication
Reference 44	Interview ▪ Marketing Manager ▪ Project Manager	Marketing undertakes all marketing related activities as specified by the formal N.P.I process. Activities such as: ▪ Undertaking customer clinics ▪ Capturing customer requirements ▪ Inputting customer requirements into the specification
Reference 45	Interview ▪ Marketing ▪ Project Manager	Cross functional problem solves issues of concept development with design at the early phases of the process on issues such as: ▪ Customer requirements ▪ Commercial costs ▪ Whether requirements can be designed ▪ Trading off design/customer conflicts
Reference 46	Interview ▪ Marketing ▪ Project Manager	Cross-functional problems solves issues of concept development with manufacturing at the early phases of the process on issues such as: ▪ Customer requirements ▪ Commercial costs ▪ Whether requirements can be manufactured ▪ Trading off manufacturing/customer conflicts

Reference 47	Interview ▪ Project Manager	Commitment by showing dedication to the following: ▪ Organisational requirements ▪ Time-scales
Reference 48	Interview ▪ Project Manager	Deployment of test engineers within the team
Reference 49	Interview ▪ Project Manager ▪ Test	Knowledge and skills in the following areas: ▪ Technologies ▪ Application of design of experiments ▪ Analytical skills ▪ Testing methods and techniques ▪ Experience
Reference 50	Interview ▪ Project Manager ▪ Test	Test undertakes all test-related activities as specified in the N.P.I process. Activities such as: ▪ Designing experiments ▪ Product testing
Reference 51	Interview ▪ Project Manager ▪ Test Manager	Test Execute work packages in parallel with: ▪ Marketing work-packages ▪ Engineering work-packages ▪ Manufacturing work-packages
Reference 52	Interview ▪ Project manager ▪ Test Manager	Test cross-functional problem solves testability with design engineering during the early phases of product development on issues such as[3]: ▪ What is to be tested? ▪ Can it be tested? ▪ Availability of resources and equipment? ▪ Trading off design/test conflicts
Reference 53	Interview ▪ Project Manager ▪ Test	Commitment by showing dedication to the following: ▪ Achieving product costs ▪ Quality ▪ Time-scales
Reference 54	Interview ▪ Project Manager	Deployment if after-sales engineers within the team. ▪ Maintenance ▪ Sales and Parts
Reference 55	Interview ▪ Project Manager ▪ After-sales Manager	After-sales team members have the appropriate skills for undertaking the required work. Skills such as the following: ▪ Maintenance skills ▪ Writing repair and maintenance procedures ▪ Communicating in field product performance
Reference 56	Interview ▪ Project Manager ▪ After-sales Manager	Undertook after-sales related activities as defined in the process. Activities such as: ▪ Writing maintenance models ▪ Setting up spare parts in stock
Reference 57	Interview ▪ Project Manager	After-sales execute work-packages concurrently with: ▪ Marketing work packages ▪ Design work packages ▪ Test work packages ▪ Manufacturing work packages
Reference 58	Interview ▪ Project Manager ▪ After-sales ▪ Design	After-sales cross-functional problem solves issues of serviceability during the concept and design phases through the following[4]. ▪ Identifies/reports opportunities for easing serviceability ▪ Reports field failure data to the design engineers
Reference 59	Interview ▪ Project Manager	Commitment by showing dedication to the following: ▪ Achieving product costs

		▪ Quality ▪ Time-scales
Reference 60	Interview ▪ Project Manager	Deployment of a matrix based team structure with the following characteristics: ▪ Balanced authority between functional managers and the project manager ▪ Lateral, and vertical lines of communication
Reference 61	Interview ▪ Project manager	Deployment of a system team with the following skills. ▪ Project manager ▪ Engineering manager ▪ Marketing manager ▪ Production manager ▪ Quality manager ▪ After-sales manager
Reference 62	Interview ▪ Project Manager	Deployment of a sub-system team organised around a product structure breakdown with the following skills. ▪ Sub-system project manager ▪ Design team leaders ▪ Manufacture team leaders ▪ Purchasing team leaders ▪ Supplier team leaders ▪ Test team leaders
Reference 63	Interview ▪ Project Manager	Deployment of an extended team with the following skills. ▪ Design ▪ Manufacture ▪ Purchasing ▪ Suppliers ▪ Test
Reference 64	Interview ▪ Project Manager	Devolved accountabilities such as the following: ▪ System team is accountable for delivering the system. ▪ Sub-system teams are accountable for sub-systems. ▪ Extended teams are accountable for delivering components.
Reference 65	Interview ▪ Project Manager	Devolved decision making such as the following: ▪ Systems team make decisions with respect to system issues ▪ Sub-system teams make decisions on sub-systems issues.
Reference 66	Interview ▪ Project Manager	Deployment of a matrix based team structure with the following characteristics: ▪ Balanced authority between functional managers and the project manager ▪ Lateral, and vertical lines of communication
Reference 67	Interview ▪ Project Manager	Deployment of a system team with the following skills. ▪ Project manager ▪ Engineering manager ▪ Marketing manager ▪ Production manager ▪ Quality manager ▪ After-sales manager
Reference 68	Interview ▪ Project Manager	Deployment of an extended team to deliver a product structure breakdown with the following skills: ▪ Design ▪ Manufacture ▪ Purchasing ▪ Suppliers ▪ Test
Reference 69	Interview ▪ Project Manager	Devolved accountabilities such as the following: ▪ System team is accountable for delivering the system.

		▪ Sub-system teams are accountable for sub-systems. ▪ Extended teams are accountable for delivering components.
Reference 70	Interview ▪ Project Manager	Devolved decision making such as the following: ▪ Systems team make decisions with respect to system issues ▪ Sub-system teams make decisions on sub-systems issues.
Reference 71	Interview ▪ Project Manager	Team members are involved in the continuous identification of improvements to enhance teamwork within product development. ▪ Suggestion schemes ▪ Financial justification of proposed benefits ▪ Evidence of implemented improvements

Information Technology

Reference 72	Interview ▪ Engineering	Deployment of Computer Aided Design Tools with the following capabilities: ▪ Solid modelling ▪ Simultaneous design capability ▪ Electronic assembly capability ▪ Data transfer capability
Reference 73	Interview ▪ Engineering	Application of CAD systems at the concept, design and manufacturing stages. Activities such as: ▪ Concept definition ▪ Design definition ▪ Production drawings ▪ Tooling designs
Reference 74	Interview ▪ Engineering	Simultaneous electronic definition of product sub-systems by demonstrating the following: ▪ The use of a single master electronic model. ▪ Defining a product structure breakdown in parallel.
Reference 75	Interview ▪ Engineering	Electronic assembly of product systems for analysis of shape and form by demonstrating the following: ▪ Assembling elements of a product structure breakdown within a single design space. ▪ Assessing interference and design space capability.
Reference 76	Interview ▪ Engineering	Electronic *analysis of product systems* for ease of maintainability by demonstrating the following: ▪ Defining modular systems. ▪ Virtually assessing ergonomics of maintenance. ▪ Simulating turnaround times.
Reference 77	Interview ▪ Engineering	Data transfer of design models with manufacturing CAM tools at the design stage by transferring the following: ▪ Transfer of components to CAM ▪ Transfer of CNC data to CNC machines ▪ Translation of design data to manufacturing process data via computer aided process planning.
Reference 78	Interview ▪ Engineering	Deployment of CAM tools for production development with the following capabilities: ▪ Solid modelling components ▪ CNC path definition ▪ Data transfer capability with CAD systems.
Reference 79	Interview ▪ Engineering	Application of CAM tools for production design by applying them to the following activities:

		▪ Tooling design ▪ CNC code definition ▪ Validating design for manufacture
Reference 80	Interview ▪ Engineering	Deployment of computational design tools with the following capabilities: ▪ Stress analysis ▪ Thermodynamics analysis ▪ Aerodynamics analysis ▪ Fluid transfer analysis ▪ Heat transfer analysis
Reference 81	Interview ▪ Engineering	Application of computational design tools at the concept and design phases for the following activities: ▪ Stress analysis ▪ Heat transfer ▪ Thermodynamics ▪ Aerodynamics ▪ Fluid analysis
Reference 82	Interview ▪ Project Manager	Deployment of a Product Data Management System with the following characteristics: ▪ A central vault ▪ Configuration management ▪ Distributed network ▪ Drawing release control
Reference 83	Interview ▪ Project Management ▪ Engineering ▪ Manufacture ▪ Purchasing ▪ After-sales ▪ Test ▪ Marketing	Upstream and downstream functions have access to the appropriate product related data throughout the N.P.I process. Data such as: ▪ Cost data ▪ Specification data ▪ Supplier data ▪ Drawing data ▪ CNC data ▪ Manufacturing process data
Reference 84	Interview ▪ Project Manager	Deployment of an integrated project management tools with the following characteristics: ▪ Definition of gannt charts ▪ Definition of pert diagrams ▪ Resource allocation capability ▪ Automatic updating capability
Reference 85	Interview ▪ Project Manager	Electronic definition of the system plan with the following characteristics: ▪ Activity phases ▪ Time lines ▪ Definition of the critical path ▪ Review gates ▪ Resource histograms
Reference 86	Interview ▪ Project manager	Electronic definition of sub-system plans with the following characteristics: ▪ Activity phases ▪ Time lines ▪ Definition of the critical path ▪ Review gates ▪ Resource histograms
Reference 87	Interview ▪ Project Manager	Teams have appropriate access to project plans through demonstrating the following characteristics: ▪ Systems team has access to all levels of the project plan ▪ Sub-systems teams have access to all levels of the project plan

Reference 88	Interview ▪ Project Manager	Team members are involved in the continuous identification of improvements to enhance teamwork within product development. ▪ Suggestion schemes ▪ Financial justification of proposed benefits ▪ Evidence of implemented improvements

Tools & Techniques

Reference 89	Interview ▪ Project Manager	Deployment of Design for Manufacture and Assembly with the following capabilities: ▪ Parts reduction ▪ Material selection ▪ Process optimisation
Reference 90	Interview ▪ Project Manager	Application of DFA during the concept and design phase for the following activities: ▪ Setting part reduction targets ▪ Parts reduction ▪ Process optimisation ▪ Definition of process assembly sequences ▪ Material selection
Reference 91	Interview ▪ Project Manager ▪ Engineering	Deployment of value analysis with the following capabilities ▪ Setting of component cost targets ▪ Ability to measure system, sub system and component costs ▪ Ability to measure cost of alternative designs
Reference 92	Interview ▪ Project Manager ▪ Engineering	Value analysis is applied at the concept and design phases for the following activities: ▪ Designing a product to meet specified cost targets ▪ Calculating system, sub-system, and component costs ▪ Calculating cost of alternative designs
Reference 93	Interview ▪ Project Manager ▪ Engineering	Deployment of Failure Mode & Effects Analysis with the following capabilities: ▪ Hazard identification ▪ Rating of hazards ▪ Defining contingency plans ▪ Implementation of plans
Reference 94	Interview Project Manager Engineering	Failure Mode & Effects Analysis is applied at the concept and design phases for the following activities: ▪ Identifying potential product failure modes ▪ To assign the likelihood of failure from field data ▪ To define contingency plans for reducing risk of hazards ▪ Implementation of contingency plans
Reference 95	Interview ▪ Project Manager ▪ Test ▪ Engineering	Deployment of design of experiments with the following capabilities: ▪ Experimental optimisation ▪ Hypothesis testing ▪ Statistical analysis
Reference 96	Interview ▪ Project Manager ▪ Test ▪ Engineering	Design of experiments is applied at the concept and design phases for the following capabilities: ▪ To design experiments to ensure all possibilities are tested ▪ To optimise experimental design for reducing costs ▪ To ensuring that testing meet quality & reliability targets
Reference 97	Interview ▪ Project Manager ▪ Engineering ▪ After-sales	A modular design methodology is targeted to give ease of product serviceability by demonstrating the following. ▪ Setting change-over time targets

		▪ Targeting ease of sub-system change-over ▪ Targeting ease of component change-over ▪ Targeting ease of parts change over
Reference 98	Interview ▪ Project Manager	The deployment of quality function deployment with the following capabilities. ▪ Customer requirements capture ▪ Weighting of customer needs ▪ Capturing technical requirements
Reference 99	Interview ▪ Project Manager	Quality function deployment is deployed during the front end of the project for the following: ▪ Capturing and weighting customer requirements ▪ Translating customer needs into technical requirements
Reference 100	Interview ▪ Project Manager ▪ Engineering	The deployment of rapid prototyping with the following capabilities. ▪ Fast development of scaled models ▪ Low cost ▪ Integration with CAE
Reference 101	Interview ▪ Project Manager ▪ Engineering	Rapid prototyping is deployed at the concept and design phases of the process to undertake the following. ▪ To define a solution as part of a tendering process ▪ To check form of components ▪ To check assembly for fit ▪ Scaled testing
Reference 102	Interview ▪ Project Manager ▪ Engineering ▪ Manufacture	Deployment of process capability studies with the following characteristics. ▪ Specification of tolerance limits ▪ Component sampling ▪ Analysis of variation
Reference 103	Interview ▪ Project Manager ▪ Engineering ▪ Manufacture	Capability studies are undertaken at the early phases of the process to undertake the following. ▪ To understand whether processes are capable. ▪ Feedback process variance into component design ▪ Take corrective action to manufacturing processes
Reference 104	Interview ▪ Project Manager	Team members are involved in the continuous identification of improvements to enhance tools and techniques for improving product development by undertaking the following. ▪ Suggestion schemes ▪ Financial justification of proposed benefits ▪ Evidence of implemented improvements

Supply Chain Management

Reference 105	Interview ▪ Project Manager ▪ Purchasing	Suppliers are selected early in the process by demonstrating selection procedures, which emphasise upon the following. ▪ Assessment of manufacturing capability ▪ Conformance to design standards and practices ▪ Conformance to I.T requirements ▪ Ability to project manage
Reference 106	Interview ▪ Project Manager ▪ Purchasing	Suppliers are integrated into the formal N.P.I process by demonstrating the following. ▪ Harmonisation of product development phases ▪ Harmonisation of key process reviews

Reference 107	Interview ▪ Project Manager ▪ Purchasing	Key suppliers are integrated into the team by demonstrating the following ▪ Location of supplier at customer facilities ▪ Attendance of supplier at product development reviews
Reference 108	Interview ▪ Project Manager ▪ Purchasing	Supplier's cross-functional problem solving with design on issues of manufacturability at the early phases of the process by demonstrating the following[3]. ▪ What is to be made? ▪ Can it be made? ▪ Whether processes are in control? ▪ Reducing the number of product parts ▪ Meeting product target costs ▪ Trading off solutions to balance cost, quality, and time
Reference 109	Interview ▪ Project Manager ▪ Purchasing	Electronic data is exchanged throughout the supply chain by demonstrating the following. ▪ Transfer of CAD drawings ▪ Invoices ▪ Invitations to tender
Reference 110	Interview • Project Manager • Purchasing	Cross functional problem solving with suppliers on test issues such as: • What is to be tested? • Can it be tested? • Design experiments • Results of experiments
Reference 111	Interview	Cross functional problem solves with suppliers engineering requirements such as: • Functionality • Interfaces • RAMS • LCC • Service
Reference 112	Interview ▪ Project Manager ▪ Purchasing	Simple tiered structure with the following characteristics. ▪ Devolved decision making to each tier level. ▪ Design capable suppliers located at the next tier ▪ Manufacturing only capable suppliers located behind design capable suppliers.
Reference 113	Interview ▪ Project Manager ▪ Purchasing	Team members are involved in the continuous identification of improvements to enhance supply chain management by undertaking the following. ▪ Suggestion schemes ▪ Financial justification of proposed benefits ▪ Evidence of implemented improvements

Project Management

Reference 114	Interview ▪ Project Manager ▪ Marketing ▪ Engineering ▪ Purchasing ▪ Manufacturing ▪ After-sales	A feasibility study to identify issues such as: ▪ Market/Customer requirements ▪ Resource requirements ▪ Financial requirements ▪ Potential sales/revenues earnings ▪ Current technology ▪ Current skills capability

Reference 115	Interview ▪ Project Manager	A specification defining the following: ▪ Lead-times ▪ Project budget ▪ Project time-scales ▪ Product cost targets ▪ product functionality ▪ Reliability targets
Reference 116	Interview ▪ Project Manager	A formal project review analysing issues such as: ▪ Do we have the resources ▪ Do we have the finances ▪ Do we have the technologies ▪ Does it have a high revenue potential ▪ Is it in line with company strategy
Reference 117	Interview ▪ Project Manager	The existence of an overall development plan for the following. ▪ Defining current and future projects across the organisation ▪ Definition of timelines for all projects ▪ Allocation of people from across the organisation ▪ Allocation of finance across the organisation
Reference 118	Interview ▪ Project Manager	Development of a system project plan defining the following. ▪ System activities ▪ Overall project timelines ▪ Overall project reviews ▪ Allocation of skills and resources ▪ Definition of cash flow
Reference 119	Interview ▪ Project Manager	Development of sub-system plans integrated within the system plan defining the following. ▪ Sub-system activities ▪ Sub-system project timelines ▪ Sub-system project reviews ▪ Allocation of skills and resources ▪ Definition of cash flow
Reference 120	Interview ▪ Project Manager	Development of work package plans defining ▪ Activity ▪ Dates ▪ Allocation name
Reference 121	Interview ▪ Project Manager	Concurrency was built into the project plans as defined by the formal N.P.I process by demonstrating the following. ▪ Definition of sub-system design and build activities in parallel ▪ Definition of process phases in parallel
Reference 122	Interview ▪ Project Manager	Development of a system project plan defining the following. ▪ System activities ▪ Overall project timelines ▪ Overall project reviews ▪ Allocation of skills and resources ▪ Definition of cash flow
Reference 123	Interview ▪ Project Manager	Development of work package plans defining ▪ Activity ▪ Dates ▪ Allocation name
Reference 124	Interview ▪ Project Manager	Concurrency was built into the project plans as defined by the formal N.P.I process by demonstrating the following. ▪ Definition of process phases in parallel
Reference 125	Interview ▪ Project Manager	The use of historical data for defining plans by emphasising upon the following.

		Historical activity time lines ▪ Historical resources ▪ Historical budget spend ▪ Strengths and weaknesses from previous projects
Reference 126	Interview ▪ Project Manager	Risk assessments are undertaken by demonstrating the following. ▪ The use of risk assessment tools ▪ Multifunctional team approach ▪ Categorisation of risks ▪ Identification of contingency measures
Reference 127	Interview ▪ Project Manager	Teams conduct regular program reviews by monitoring the following: ▪ Is the project on time? ▪ Is the project to cost? ▪ Is the project meeting specified quality/reliability targets? ▪ Is the project to budget?
Reference 128	Interview ▪ Project Manager	Continuous programme risk assessments are undertaken through demonstrating the following: ▪ Multifunctional team approach ▪ Categorisation of risks ▪ Identification of contingency measures
Reference 129	Interview ▪ Project Manager	Deployment of a project de-brief through demonstrating the following: ▪ Multifunctional team approach ▪ Identification of strengths and weaknesses ▪ Documentation of strengths and weaknesses ▪ Building lessons learn't within future projects
Reference 130	Interview ▪ Project Manager	Team members are involved in the continuous identification of improvements to enhance project management by undertaking the following. ▪ Suggestion schemes ▪ Financial justification of proposed benefits ▪ Evidence of implemented improvements

References

[1] This section is based on the following. Product Introduction Management, Lucas Varity, Product introduction Manual, Part 1-Mandatory Elements, Issue 2, Dec 1998. Johnson Controls, Product launch System. Charles Tennant, Rover Group, Common Business Environment, Project Management, University of Warwick, 1998

[2] Based on achieving Design for Manufacture by Corbet, Design for Manufacture, Strategies, Principles & Techniques, Addison Wesley Publishing Company, 1991

[3] Based on achieving Design for testability by Turino J, Managing Concurrent Engineering, Buying Time to Market, Van Nostrand Reinhold

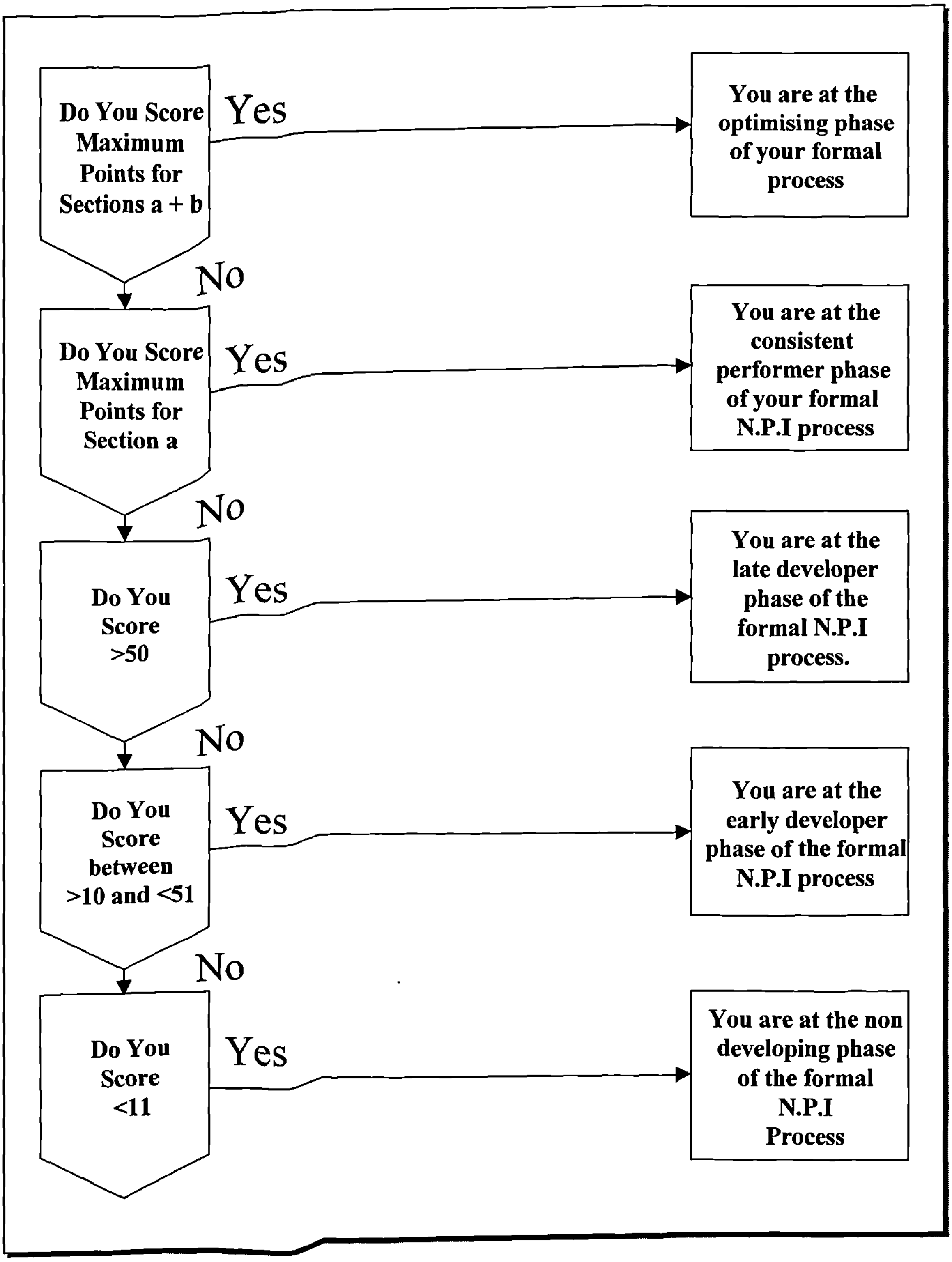
[3] Based on achieving Design for testability by Turino J, Managing Concurrent Engineering, Buying Time to Market, Van Nostrand Reinhold

[4] Based on achieving Design for Serviceability, Design for X, Concurrent Engineering Imparatives, Edited C.Q Huang, Chapman & Hall, 1996

Appendix 2 Maturity Assessment Flow Diagram

Introduction

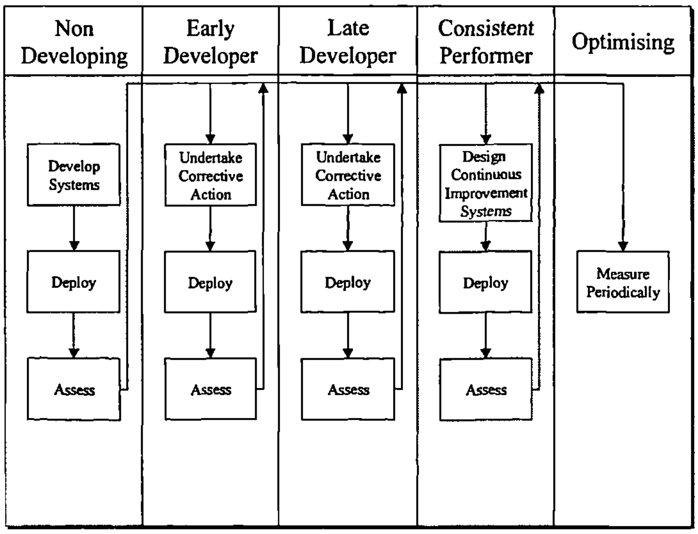
The following flow diagram is to be used to ascertain a maturity level for a current and future state as sections 5.1.3 and 5.1.4 first introduced.



Appendix 3 Generic Planning Tool

Introduction

The following introduces the generic-planning tool and the activity checklists for each phase as first introduced in section 5.2.2.. The checklists are to be used for indicating what types of activities are to be planned, when utilising the generic-planning tool to build a project plan.



Phase: Develop Systems
▪ *Design and Define New Processes, Tools, Technologies and Structure.*
▪ *Identify Organisational Training Requirements.*
▪ *Identify Resources for Supporting Deployment.*
▪ *Identify Potential Implementation Projects.*
▪ *Identify Means for Communicating New Solutions.*
▪ *Identify and Develop Continuous Improvement Mechanisms If Required.*

Phase: Deploy
▪ *Undertake Organisational Training.*
▪ *Set Up Project(s) and Deploy New Systems.*
▪ *Monitor the Progress of Implementation.*
▪ *Provide Facilitation.*

Phase: Assess
▪ *Undertake Post Project Review.*
▪ *Check Whether Systems Have Been Implemented As Intended.*
▪ *Understand Strengths and Weaknesses.*
▪ *Decide Whether Corrective Action Is Required.*

Phase: Undertake Corrective Action
▪ *Understand Gap Analysis and Requirements.*
▪ *Re-Design System to Take Weaknesses Into Consideration.*
▪ *Identify New Training.*
▪ *Identify Resources for Supporting Deployment.*

Phase: Design Continuous Improvement Systems	
▪	*Identify Continuous Improvement Practices.*
▪	*Identify Necessary Training.*
▪	*Communicate New Practices And Purpose To The Organisation.*

Appendix 4

Score at L.T.I for a Formal N.P.I Process

Criteria	Findings	Score
A Standard Documented New Product Introduction Process	**No process present**	**0**
Clear Definition of Concept Design Activities	**No process present**	**0**
Clear Definition of Product Design and Development	**No process present**	**0**
Clear Definition of Test Development Activities	**No process present**	**0**
N.P.I Process Is Defined to Different Levels of Detail	**No process present**	**0**
Concurrency is Built into the Process	**No process present**	**0**
The Formal N.P.I Process is Used for Defining Project Plans	**No process present**	**0**
Continuous Identification of Appropriate Improvements to Enhance Product Development Activities	**No process present**	**0**
Total Score Benchmark for a N.P.I Process	**No process present**	**0**

Score at L.T.I for Teamwork

Engineering

Deployment of a Project Manager Who is Responsible for Delivering the Project.	**Project Manager was deployed with all relevant skills.**	**3**
The Project Is Responsible for Undertaking all Project Related Responsibilities.	**Complete responsibility for delivering to cost, quality & time.**	**3**
Total Score for Project Management		**6/6**

Engineering

Deployment of Design Engineers within the Multifunctional Team.	**Design engineers were deplyed for engineering the project.**	**3**
Design Have the Appropriate Skills for Effectively Undertaking their Work.	**Design engineers have appropriate functional skills but did not have skills for enabling design philosophies.**	**2**
Design Engineers Undertake all Design Related Activities As Specified in the Process.	**No process was deployed**	**3**
Design Engineers Execute Work Packages Concurrently with Down Stream Work Packages.	**No evidence of this was found.**	**0**
Cross-Functional Problem Solves Design Issues with Marketing at the Early Phases of the Process.	**No evudence of this was found**	**0**
Cross-Functional Problem Solves Design Issues with Manufacture at the Early Phases of the Process.	**No evvidence of this was found.**	**0**
Cross Functional Problem Solves Design Issues with Test at the Early Phases of the Process.	**This was reported to occur on the project.**	**3**
Cross Functional Problem Solved Design Issues with Purchasing at the Early Phases of Product Development.	**No evidence was found to support this process.**	**0**
Design Engineers are Committed to their Projects.	**Design engineers were found to be committed to delivering the project.**	**3**
Total Score for Engineering		**14/27**

Manufacture

Deployment of Manufacturing Engineers within the Team.	**Manufacturing engineers were deployed on the project**	**3**
Manufacturing Have the Appropriate Skills for Effectively Undertaking the Work.	**Manufacturing engineers have appropriate functional skills but did not have skills for enabling design philosophies.**	**2**
Manufacturing Engineers Undertake Manufacturing Related Activities as Specified in the Process.	**No process was present**	**0**
Manufacturing Engineers Execute Work Packages Concurrently with Up Stream Activities.	**No evidence was found to support this criteria.**	**0**
Cross Functional Problem Solves Issues of Manufacturing Process Capability with Design Engineering at the Early Phases of the Process.	**No evidence was found to support this criterion.**	**0**
Cross Functional Problem Solves Issues of Manufacturing Process Capability with Marketing During Concept Development.	**No evidence of this was found to support this criterion.**	**0**
Manufacturing Engineers are Committed to their Projects	**Manufacturing engineers were committed to the projects.**	**3**
Total Score for Manufacture		**8/21**

Purchasing Engineers

Deployment of Purchasing Engineers within the Multifunctional Team	**Purchasing engineers were deployed on the project.**	**3**
Purchasing Engineers Have the Appropriate Skills for Effectively Undertaking their Work.	**Manufacturing engineers have appropriate functional skills but did not have skills for enabling design philosophies.**	**2**
Purchasing Undertake All Purchasing Related Activities As Specified in the Formal N.P.I Process.	**No process was present**	**0**
Purchasing Engineers Execute Work Packages Concurrently with Upstream and Downstream Work Packages	**No evidence was found to support this criteria**	**0**
Cross Functional Problem Solved Supplier Issues with Design at the Early Phases of the Process.	**No evidence of this was found**	**1**
Purchasing Engineers are Committed to their Projects	**Manufacturing engineers were committed to the project.**	**3**
Total Score for Purchasing		**9/18**

Marketing Personnel

Deployment of Marketing Team Members within the Team.	**Marketing were deployed but were only at the beginning of the process.**	**1**
Marketing Team Members Have the Appropriate Skills for Undertaking the Work.	**Marketing have appropriate skills from a functional perspective but not a cross-functional perspective.**	**3**
Marketing Undertake all Marketing Related Activities As Specified By the Formal N.P.I Process.	**No process was deployed.**	**0**

Cross Functional Problem Solves Issues of Concept Development With Design At The Early Phases of the Process.	**No evidence of this was found.**	**0**
Cross Functional Problem Solves Issues of Concept With Manufacture at the Early Phases of the Process.	**No evidence of this was found.**	**0**
Marketing Engineers Are Committed to their Projects.	**Marketing were committed to the project.**	**3**
Total Score for Marketing		**7/18**

Test Engineers

Deployment of Test Engineers within the Team.	**Test engineers were deployed on the project.**	**3**
Test Team Members Have the Appropriate Skills for Undertaking their Required Work.	**Marketing has appropriate skills from a functional perspective but not a cross-functional perspective.**	**3**
Test Undertake All Test Related Activities As Specified in the Process.	**No formal N.P.I. process was present.**	**0**
Test Engineers Execute Work Packages Concurrently With Upstream and Downstream Processes.	**No evidence of this was found on the project.**	**0**
Cross Functional Problem Solves Issues of Testability with Design Engineering During the Early Phases of Product Development.	**This was reported to have occured on the project.**	**3**
Test Engineers Are Committed to the Project.	**Test engineers were committed to the project.**	**3**
Total Score for Test		**12/18**

After Sales Engineers

Deployment of After Sales Engineers Within The Multifunctional Team	**Aftersales were deployed on the project.**	**3**
After Sales Team Members Have the Appropriate Skills for Undertaking the Required Work.	**Aftersaloes have appropriate skills from a functional perspective but not a cross-functional perspective.**	**3**
After Sales Execute Work Packages Concurrently with Upstream and Downstream Processes.	**No evidence of this was found on the project.**	**0**
Cross Functional Problem Solves Issues of Serviceability with Engineering During the Concept and Design Phases.	**No evidence of this was found on the project.**	**0**
After Sales Engineers are Committed to the Project	**Aftersales engineers are committed to the project.**	**3**
Total Score for After Sales		**9/15**

Team Structure

Deployment of a Matrix Based Team Structure.	**This was deployed for the project.**	**3**
Deployment of a System Team Based Around a Work Structure Breakdown.	**This was deployed on the project.**	**3**
Deployment of Sub System Teams Organised Around a Product Structure Breakdown.	**This was deployed on the project.**	**3**
Deployment of an Extended Team	**This was deployed on the project.**	**3**

Devolved Accountabilities	**This was deployed.**	**3**
Devolved Decision-Making At Each Level of the Work Break Down Structure.	**This was not deployed to the lowest level.**	**1**
Total Score for Team Structure		**16/18**

Section B

Team Members Are Involved in the Continuous Identification of Improvements to Enhance Teamwork within the Organisation.	**This was not deployed on the project.**	**0**
Total Score for Continuous Improvement		**0/3**

Information Technology

Computer Aided Design

Deployment of Computer Aided Design Tools	**CAD was deployed which had simultaneous design, solid, and electronic assembly capability.**	**3**
Application of CAD Systems at the Concept, Design and Manufacturing Phases.	**Some CAD was deployed for concept and detailed design definition. However, only part of the vehicle was defined.**	**1**
Simultaneous Electronic Definition of Product Sub Systems.	**Only part of the vehicle was defined using solid modelling techniques.**	**1**
Electronic Assembly of Product Sub Systems for Analysis of Shape and Form.	**No evidence was found**	**0**
Electronic Analysis of Product Systems for Ease of Maintenance.	**No evidence was found**	**0**
Data Transfer of Solid Models with Manufacturing CAM Tools	**No evidence was found**	**0**
Total Score for CAD		**5/18**

Computer Aided Manufacture

Deployment of CAM Tools for Manufacturing Systems Development.	**No evidence was found**	**0**
Application of CAM Tools for Production Design.	**No evidence was found**	**0**
Total Score for CAM		**0/6**

Computational Design Tools

Deployment of Computational Design Tools.	**FEA was deployed for assessing the structural integrity of the vehicle.**	**3**
Application of Computational Design Tools at the Concept and Design Phases.	**FEA was deployed during the detailed design phase.**	**3**
Total Score for Computational Design Tools		**6/6**

Product Data Management

Deployment of a Product Data Management System.	**No evidence was found**	**0**
Upstream and Downstream Functions Have Access to Appropriate Product Related Data Through the N.P.I Process.	**No evidence was found**	**0**
Total Score for Product Data Management		**0/6**

Integrated Project Management Tools

Deployment of Integrated Project Management Tools	**Evidence was found**	**3**
Electronic Definition of the Programme Plan	**Evidence was found**	**3**
Electronic Definition of Project Plans	**Evidence was found**	**3**
All Team Have Appropriate Access to Project Plans	**Evidence was found**	**3**
Total Score for Project Management Tools		**12/12**

Section B

Continuous Identification of Improvements to Enhance the Contribution of I.T To Product Development	**No evidence was found**	**0**

Tools & Techniques

Design for Manufacture & Assembly

Deployment of Design for Manufacturability and Assembly Tools.	**No evidence was found**	**0**
Design for Manufacture and Assembly are Applied During the Concept and Design Phases.	**No evidence was found**	**0**
Deployment of Value Analysis.	**No evidence was found**	**0**
Value Analysis is Applied By Design During the Concept and Design Phases.	**No evidence was found**	**0**
Deployment of Failure Mode & Effects Analysis.	**FMEA was deployed on the project**	**3**
Failure Mode & Effects Analysis is Applied During the Concept and Design Phases.	**FMEA was deployed on the door system**	**1**
Deployment of Design of Experiments	**No evidence was found**	**0**
Design of Experiments is Applied During the Concept and Design Phases.	**No evidence was found**	**0**
A Modular Design Methodology Is Targeted to Give Ease of Product Serviceability.	**Some modular design philosophies were deployed.**	**1**
Deployment of Quality Function Deployment	**QFD was deployed for capturing customer requirements.**	**3**
Quality Function Deployment Is Applied at the Front End of the Process	**QFD was applied to translate customer requirements into technical solutions at the early phases of the process.**	**3**
Deployment of Process Capability Studies	**No evidence was found**	**0**
Capability Studies Are Undertaken At The Early Phases of the Process	**No evidence was found**	**0**
Total Score		**11/39**

Section B

Continuous Identification of Improvements to Maximise the Contribution of Tools & Techniques to Product Development	**No evidence was found**	**0**
Total Score		**0/3**

Supply Chain Management

Suppliers Selected Using Standard Selection Procedures	**No evidence was found**	**0**
Suppliers are Identified Early in the Process	**No evidence was found**	**0**
Suppliers are Integrated into the Formal N.P.I Process	**No evidence was found**	**0**
Key Suppliers are Apart of the Multifunctional Team	**Key strategic suppliers were integrated into the team and were responsible for delivering an engineering and production work package.**	**3**
Suppliers Cross Functional Problem Solve with Design On Issues of Process Capability at the Early Phases of the Process.	**Evidence was found to support that engineering and suppliers cross-functional problem solved issues of manufacturability with engineering.**	**3**
Electronic Data is Exchanged Throughout the Supply Chain	**No evidence was found.**	**0**
The Supply Chain is Structured into Simple Tiers		**3**
Total Score		**9/21**

Section B

Continuous Identification of Improvements for Improving the Contribution of the Supply Chain to Product Development	**No evidence was found**	**0**
Total Score		**0/3**

Project Management

A Feasibility Study for Identifying the Need	**A feasibility was conducted**	**3**
A Project Specification Defining Both Product and Project Requirements	**A project specification was defined.**	**3**
An Overall Development Plan to Ensure the Correct Prioritisation of Projects	**No evidence was found.**	**0**
The Development Plan Has a System in Place that Takes into Account Finite Development Capacity	**No evidence was found.**	**0**
Finite Resource is Taken into Consideration When Developing the Programme Plan	**No evidence was found**	**0**
The Development of an Overall Programme Plan	**A program plan was developed,**	**3**
The Development of Sub System Plans	**Sub-system work plans were defined.**	**3**
The Development of Work Package Plans	**No evidence of work package plans.**	**0**
Concurrency is Built into the Project Plans	**No evidence was found.**	**0**
The Use of Historical Time Data for Project Plan Definition	**No evidence was found**	**0**
A Project Risk Assessment is Undertaken	**No evidence was found**	**0**
Teams Conduct Regular Program Reviews for Monitoring Progress	**No evidence was found**	**0**
Continuous Risk Assessments are Undertaken Throughout the Project to Identify New Hazards and Implement Contingency Plans	**No evidence was found**	**0**
Deployment of a Project De Brief	**A project de-brief was undertaken.**	**3**
Total Score		**15/42**

Section B

Continuous Identification of Improvements to Maximise the Contribution of Project Management to Product Development	**No evidence was found**	**0**
Total Score		**0/3**

Performance Measures

The Project Is Delivered on Time.	**3**
Phases of Product Development are Executed on Time	**0**
The product is Delivered to Cost	**0**
The Actual Project Cash Flow Meets the Predicted Project Cash Flow	**0**
The Overall Project is Delivered to Budget	**0**
Engineering Design Changes Occur at the Front End of Product Development	**0**
All Internal and External Manufacturing Processes are Under Control	**0**
The Product Meets Reliability and Maintainability Targets	**0**
The Product Meets Functional Requirements	**3**
Total Score	**6/27**